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DS2 CONTAINER AND WEATHERPROOFING STUDY

David C. Stark
R. William Mengel

GENERAL MANAGEMENT ASSOCIATES
Abingdon, MD 21009

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This report presents the results of a market survey of commercial hazardous waste management, container manufacturing, and weatherproofing firms to determine the state-of-art in hazardous material container weatherproofing. This information is intended to improve the shelf life of the containers used for contingency stockage of DS2 decontaminant. Included in this report are the methodology, results, and conclusion of the assessment.

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EXECUTIVE SUMMARY

The objective of the "DS2 Container and Weatherproofing Study" is to identify and recommend candidate materials, methods and containers capable of withstanding common DS2 storage conditions. This effort is in support of the U.S. Army's program to identify improved methods for containerization and protection from the environment for DS2 in long-term storage.

Efforts under this task identified and conducted a preliminary assessment of materials, containers and methods used in industry for handling and storing highly corrosive liquids. Materials and methods for coating and weatherproofing steel containers also have been examined. In accomplishing these reviews nearly 100 private sector firms were surveyed. Firms in hazardous material handling, container manufacturing, and coating and weatherproofing were contacted to determine the state of current technology in these areas.

Key findings in the study are:

- Under current requirements of the Resource Conservation and Recovery Act, the method and times for storage of hazardous materials are limited to 90 days for waste generators and one year for storage and disposal sites. Hence, long-term storage techniques are not addressed.

- Non-burnable hazardous wastes stored in landfills are not contained in a manner that ensures corrosion resistance. Landfills are constructed with impermeable polyethylene liners to prevent contaminants from leaking outside the landfill. These landfills are also designed to drain any liquid leachate into a sump for recovery and incineration. Thus, a certain amount of container seepage over time is viewed as beneficial in reducing the overall hazard of the landfill.

- A range of potential alternatives for improving DS2 containers were developed from the surveys. These include:

    - The use of stainless steel containers

    - Use of cold-rolled steel with an inner liner of selected polymers

    - Use of one of selected polymers

    - Use of shrink-wrap overpack on the container

    - Substitute silver solder for the currently used lead solder

From the study findings, a preliminary range of recommendations has been developed. These recommendations are nominally rank ordered based solely on technical feasibility.

- Package DS2 in stainless steel containers
- Use silver solder for the end closures
- Use a shrink-wrap overpack
- Make a container from a compatible polymer
- Apply an internal polymer liner to the current container

PREFACE

The work described in this report was authorized under Contract No.DAAA15-87-D-0021, Task 089. This work was started in January 1990 and completed in September 1990.

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DS2 CONTAINER AND WEATHERPROOFING STUDY

1. BACKGROUND

DS2 is the standard chemical agent decontaminant for the U.S. Army. DS2 is a homogeneous mixture of Diethylenetriamine (69-71%), sodium hydroxide (1.9-2.1%) and ethylene glycol monomethylether (methyl cellosolve) (remainder). This mixture is corrosive to some materials, and can cause softening of plastics and paints. DS2 is packed in steel containers of three sizes (Ref. 1):

- 1-1/3 quart refills for the M11 Decontaminating Apparatus
- 14-liter (3.7 gallons) punch-seal containers for the M13 Decontaminating Apparatus
- 5-gallon pail for bulk decontamination operations

There have been a number of reports from depots and field storage sites of leaking and/or corroded DS2 containers. A reasonable initial assumption would be that the caustic contents were finding vulnerable points in the container and corroding from the inside out. However, previous investigations have determined that the leakage is more often caused by prolonged environmental exposure of the welds or solder closures at the lap joints and end caps of the containers.

The result of this corrosion on the container is an eventual loss of seal integrity, which allows air to enter the can, and DS2 to subsequently seep out. The contents of the container may polymerize, resulting in a useless gel. Seepage of the contents may present an environmental and health hazard because of the corrosive and toxic nature of DS2. In either case, the container and its contents must be properly disposed of and replaced, thereby increasing the life cycle cost of maintaining the necessary wartime stockpile levels of DS2 material.

2. OBJECTIVE, PURPOSE AND SCOPE

2.1 OBJECTIVE

The overall objective of this task is to identify and recommend candidate materials, methods and containers able to withstand common DS2 storage conditions. In support of this objective, the task requires the determination of materials, containers and methods used in the hazardous waste industry for handling and storing highly corrosive liquids. In direct response to current DS2 packaging, the study is also to determine materials and methods used in industry for coating and weatherproofing steel containers.

2.2 PURPOSE AND SCOPE

The purpose of the study is to develop data to support the U.S. Army in defining alternative approaches to the packaging of DS2 in order to eliminate the causes of current container leakage problems. Through this study, the Government will be able to identify and solicit information from private sector companies which might contribute to the updating of the DS2 packaging technical data package (TDP).

The scope of the task includes contacting hazardous materials, plastics, and weatherproofing firms to obtain information on containerization and weatherproofing materials and methods. At least 50 companies will be surveyed, with no geographic restrictions. Companies will represent a range of sizes, based on annual revenues.

3. PROCEDURE FOR STUDY

3.1 SURVEY QUESTIONNAIRE

The first portion of the task was to develop a questionnaire for use as a framework for discussions. The questionnaire was submitted to the Government for comments and approval. The final questionnaire is presented as Figure 1.

3.2 COMPILATION OF THE ADDRESS LISTS

Concurrent with questionnaire preparation and Government approval, the task team compiled a list of 99 addresses of companies identified as hazardous waste handlers, container manufacturers, or anti-corrosion coating suppliers. The task team used the Thomas Business Register, 1989 edition, as the primary source, and extracted the companies deemed most likely, from the limited descriptions of capabilities, to be in the field of interest. From an initial list of more than 500 companies, the final mailing list of 99 companies was complied. A list of the companies contacted is presented in Appendix A.

3.3 CONTACTS WITH COMPANIES

Each of these companies was mailed a survey questionnaire, and then was contacted by telephone. The initial telephone contact served to establish a point-of-contact (POC) by name and as a means to schedule a follow-up call for further information gathering after the POC had a chance to review the survey questionnaire. Subsequent contact(s) were used to complete the data gathering task.

I. General Information

A. Corporate Identification

1. Name of Company

2. Address of Company Headquarters

B. Corporate Description

1. Approximate Annual Gross Sales

2. Number of Personnel

3. Has your company produced containers conforming to Government specifications?

4. If your company purchases the containers used, rather than making your own, please list the suppliers.

II. Containers

1. Does your firm handle corrosive/alkaline hazardous wastes/materials? What specific materials do you handle?

2. If yes, what Standing Operating Procedures or regulations are followed in your handling and disposal?

3. What types of containers do you use for corrosive wastes?

4. What material(s) are they made of, what gauge/thickness is the material, and what sizes do the containers come in?

5. By what methods/materials are the containers fabricated and sealed?

6. a. How long are the materials stored in the container?

   b. What effects do the corrosive materials have on the containers?

Figure 1

Hazardous/Corrosive Material Container Questionnaire

7. What are the environmental conditions under which the materials are stored?

8. Are the filled and sealed containers readily transportable? Can they be subjected to rough handling? (IAW Military Specifications). With which military specifications, if any, do they comply?

9. What are examples of materials stored in these containers?

10. What type(s) of labeling do you use on your containers? How is it applied (printed labels, stenciling, silk screening, etc.)?

11. Would you prefer to use another method to label the containers? If so, what type?

12. Are the containers you presently use considered superior to those generally used in industry today?

13. If you do not manufacture your own containers, skip to Section IV.

III. Container Manufacturers

1. Do you make containers from carbon steel? What gauge carbon steel? What are the available capacities?

2. How do you seal your carbon steel containers? If welded/soldered, how many welds/solders?

3. What other materials would be appropriate for DS2 containers?

4. Can you make containers using only two pieces (container and lid) suitable for holding DS2?

5. Do you apply corrosion resistant coatings to your containers? If so, what types?

6. Are test samples available? Are test reports available?

7. Would you be willing to fabricate containers for the U.S. Government? Do you have any reservations about dealing with the Federal Government?

Figure 1 (Continued)

8. Are any of your processes/materials proprietary in nature?

9. Can your company support a production rate of 100,000 cans per year? What is the approximate cost per can at this production rate?

IV. Weatherproofing

1. What type of materials/polymer coatings are used by your company to weatherproof/preserve products in metal containers (e.g., spray coatings, dip coatings, barrier bags, encapsulation)?

2. Is your weatherproofing method/material transparent?

3. What thickness is customarily used?

4. Is your weatherproofing method/material easily applied? What equipment is required? Under what conditions can it be applied?

5. Can your company support weatherproofing of containers at the rate of 100,000 cans per year? What is the approximate coating cost per square foot at this rate of production?

6. Are test samples, products, or containers available? Are any test reports available?

7. Can you apply your weatherproofing method/material to containers which we provide? Is there a set fee for such work?

8. Under what conditions can your weatherproofing method/material be used?

9. Is your weatherproofing method/material compatible with Chemical Agent Resistant Coating (CARC) per MIL-STD-171? Is it compatible with polyurethane based coating systems in general? Is it compatible with alkyd-based coatings?

10. How well do the labels placed on the containers hold up under weathering/storage?

11. Are the materials used to weatherproof in and of themselves considered hazardous material/waste?

Figure 1 (Continued)

12. Do the weatherproofing materials present any unusual safety or health hazards/concerns?

13. Are there any lessons learned about storage of corrosive/alkali based hazardous wastes/materials which you can recount?

V. General Comments

Figure 1 (Continued)

4. RESULTS OF THE SURVEY

Due to the contractual requirement to contact "not less than 50 firms", the task team deliberately canvassed more firms than required. Prior experience with this type of survey indicated that the typical response rate would be about 60% of the firms initially contacted. Of the 99 firms selected for initial contacts, 50 were eventually dropped from further consideration, for a variety of reasons.

More than half of the companies selected disqualified themselves, stating that their product line did not match the DS2 container requirements or that they had no desire to deal with Government contracts. The following lists the various reasons given for not participating in the survey:

- Product line does not match the requirements for DS2 containers (too large, too small, wrong materials) (19 firms)
- Firms improperly identified from the Thomas Register (warehouses for containers, nuclear waste container manufacturers, air pollution mitigators) (5 firms)
- Businesses with no desire to accept Government or military contracts (2 firms)
- Dropped hazardous waste handling line of business (1 firm)
- Gone out of business, no telephone number listed, or moved leaving no forwarding address (9 firms)
- Did not respond to repeated contacts (14 firms)

Many companies contacted informed the task team that they would simply use containers which conformed to the appropriate Department of Transportation (DOT) transportability codes for the class of materials into which DS2 falls. From the Material Safety Data Sheet (MSDS), DS2 was identified as an Alkaline Corrosive Liquid, N.O.S., which is covered by 49 Code of Federal Regulations (CFR) 173.249. The task team subsequently contacted the Department of Transportation Research and Special Program Administration (DOT-RSPA), and received a copy of the applicable paragraphs in 49 CFR 173 (Ref. 2) and packaging instructions 809 and 813 for air and water transportation. These extracts are attached at Appendix B. These companies indicated no further or more stringent requirements were necessary for their purposes.

The companies contacted were nearly unanimous in their surprise that they were contacted concerning long-term storage of caustic and hazardous wastes. Hazardous waste handling companies, under the current requirements of the Resource Conservation and Recovery Act (RCRA), are restricted in the methods and time for which they are allowed to store wastes at various sites. Transfer, Storage, and Disposal (TSD) sites are limited to one year, while hazardous waste generators are limited to 90 days.

Further, most of the companies who handle and store hazardous waste also have hazardous waste destruction facilities, most often incinerators. A company which has large amounts of liquid hazardous waste stored on-site is not operating its incinerator efficiently. Long-term storage of hazardous wastes for these companies is measured in weeks or months, rather than years or decades, as is required for DS2 storage. For this reason, most hazardous waste handlers could not begin to suggest proven methods for weatherproofing containers beyond painting them or warehousing them.

Several companies contacted had landfill facilities for long-term storage of non-burnable wastes. Under current laws, most of these wastes are solids, often contaminated with hazardous liquids. When queried about corrosion protection, the response was usually that corrosion protection of the containers in a landfill was rarely considered.

Modern landfills are lined with thick polyethylene sheets, which drain any liquid seepage to a sump, where pumps remove the liquid for subsequent treatment. Several POCs even suggested that some corrosion of the waste drums was beneficial, as the liquids which seeped into the sump were burnable, but not ordinarily economically recoverable, hence the long-term landfill storage. Any liquid wastes which percolated out of their solid matrix and were recovered at the sump could be pumped into drums and taken to an incinerator, thereby reducing the level of hazard in the landfill.

Several companies were reticent to give "free advice" to the Government, but would be quite happy to sign a contract to develop a container which would meet the DS2 storage requirements. One individual in particular, Dr. Ahmed of CHEMAREX, stated that he had an idea which his experience indicated would do the job. He further stated that he had a number of potential manufacturers lined up and interested. He wanted, however, to protect his business and financial interests, and would not reveal his idea to the task team. The Project Engineer suggested that CHEMAREX submit their concept to the Government in the form of an unsolicited proposal, and provided them with the name and address of the Contracting Officer's Representative.

Those companies which did make recommendations for improved containers offered the following techniques:

- Use stainless steel for the container.
- Use cold-rolled steel with an inner liner of:
  - polyethylene
  - epoxy/epoxy-phenolic
  - urethane
- Use one of the following polymers:
  - high-density polyethylene (HDPE)
  - fluorinated HDPE
  - polypropylene
  - polyetheretherketone (PEEK)
  - fiberglass composite
  - other fluorinated polymers
- Use a shrink-wrap overpack on the can.
- Over coat the paint on the can with:
  - sprayable elastomeric coating (urethane or other)
  - polyurethane (currently used)
  - epoxy
- Change from lead solder to silver solder.

5. DISCUSSION OF FINDINGS

5.1 STAINLESS STEEL

Several companies recommended the use of stainless steel to manufacture the cans. Stainless steel exhibits excellent corrosion resistance. Stainless steel containers are made by many firms and are widely used commercially. Stainless steel is, however, four to five times more expensive than carbon steel or cold-rolled steel (One firm priced carbon steel at $0.35/pound and stainless at $1.53 per pound, or 4.4 times the cost of carbon steel.) While this may solve the long-term storage problem, it would greatly increase the cost.

5.2 LINED-STEEL CANS

Several recommendations for cans lined or coated with a chemical resistant polymer were made. Polyethylene liner bags are available commercially, but may not be useful for the production of DS2. Cans coated with a chemical resistant material, such as polyethylene, polypropylene, polyurethane, or epoxy/epoxy-phenolic

materials may show some enhanced resistance to corrosion and leakage, but an internal barrier would not solve the problem of environmental corrosion of the seals.

5.3 POLYMERIC CONTAINERS (Ref. 3)

A number of companies suggested the use of polymeric containers to replace the current materials. The polymer recommended most often was polyethylene, but polypropylene and fiberglass composites were also mentioned. Previous studies have indicated that DS2 is indeed compatible with polyethylene and polypropylene, but that polyethylene begins to crack and seep under long-term high temperature storage. Polypropylene is reported to have better high-temperature properties, but is also more brittle, and may suffer under rough handling. (Ref. 4)

One polymer specifically suggested by the Contracting Officer's Representative (COR) was polyetheretherketone (PEEK). PEEK is a semicrystalline aromatic thermoplastic which is reported to be quite tough. The glass transition temperature of PEEK is about 143°C (289°F), and PEEK has a particularly high fracture energy of about 500 J/m^2. (Ref. 5)

PEEK is currently produced by ICI Advanced Materials. Contact with representatives from ICI indicates that PEEK would have no problems containing sodium hydroxide, but that no data are available for the other two components. The representative was not sure that PEEK would be able to contain DS2 for the length of time needed for the required shelf life. PEEK shows excellent chemical resistance to glycols, methanol, ethanol, diethylamine and diethylether in short term testing (seven days immersion at 200°C (420°F)). Longer tests have not been conducted. A more complete breakdown of the characteristics is presented at Appendix C. Samples are being obtained for Government testing.

One company makes containers of polyethylene with an internal fluorocarbon barrier which is claimed to improve polyethylene's chemical resistance. Samples of the containers were obtained for subsequent Government testing.

Another polymer specifically suggested by the COR for investigation was KYNAR (polyvinylidene fluoride, PVF_2). KYNAR is one of a number of fluorinated polymers commercially available, which include TEFLON (polytetrafluoroethylene, TFE), KEL-F (polychlorotrifluoroethylene, CTFE), FEP (a copolymer of TFE and hexafluoropropylene) and HALAR (a copolymer of CTFE and ethylene).

TEFLON is the most chemically resistant plastic commercially available and is unaffected by acids and alkalies (except high temperature fluorine and chlorine gas, and molten metals) up to 500°F (260°C). TEFLON, however, is difficult to work with, requiring complicated powder-metallurgy techniques.

KEL-F is also highly chemical resistant, can be used at temperatures up to 350°F (180°C), and can be made into a transparent film. KEL-F is expensive ($25-30 per pound) and cannot be used as a shrink-wrap. Further information is presented at Appendix D.

FEP is similar to TFE, in that it has good chemical resistance to 400°F (200°C), and the advantage that it can be extruded on conventional extrusion equipment.

KYNAR is reported to have excellent resistance to acids and alkalines up to 300°F (150°C) and can be extruded. However, KYNAR is not recommended for use with organic amines. (Ref. 6) Further information is presented at Appendix E.

HALAR also has good chemical resistance up to 300°F (150°C) and can be extruded.

Another compound is perfluoroalkoxy (PFA), which has similar properties to FEP at temperatures approaching 600°F (300°C).

The tables in Appendix F summarize information dealing with commercially available polymers.

5.4 FIBERGLASS COMPOSITE CONTAINERS

Several companies contacted recommended the use of fiberglass composite containers for replacement DS2 containers. Fiberglass composites consist of polymeric matrices reinforced with fibers of various types, which can provide a wide range of flow properties, stiffness, and strength (Ref. 7). Fiberglass is, in effect, a generic name, as fibrous reinforcement can be provided by a wide variety of materials, such as aramid fibers, carbon whiskers, and other natural and artificial fibers, as well as glass filaments. One form of glass, C-glass, based on a soda-lime borosilicate composition, is particularly useful because of its extremely high resistance to chemical corrosion. (Ref. 7)

Matrix selection is an important design consideration for fiberglass composites. Current resin (matrix) chemistry can accommodate nearly every conceivable product application. Common matrices used are (Ref. 7):

- Epoxy
- Polyester
- Phenolic
- Melamine
- Polyurethane
- Polyamide
- Polycarbonate
- Polyether
- Polystyrene
- Polypropylene
- Polyethylene
- Poly(ethylene-co-vinyl acetate)

Polyesters are some of the most common matrices, due to their adequate resistance to water and chemicals, weathering, aging, and low cost. Polyesters, however, can only withstand temperatures to about 80°C (176°F). (Ref. 5)

Epoxy matrices are more expensive than polyesters, but have better moisture resistance and a higher useful temperature range. The most important variety of epoxy matrices is a condensation product of epichlorohydrin and bisphenol A. (Ref. 5)

An important problem with polymer matrices is associated with environmental effects. Polymers can degrade at moderately high temperatures and through moisture absorption. Moisture absorption causes swelling and can lead to severe internal stresses. (Ref. 5)

The following table presents a comparison of some of the more common fiberglass materials. (Ref. 8)

Table 1. Typical properties--unreinforced resin casts

Resin	Physical properties						Chemical resistance properties			
	Flexural strength MPa	Tensile strength MPa	Tensile modulus GPa	Elongation %	Heat deflection temperature °C	Normal thermal usage limit °C	Water	Solvent	Acid	Alkali
Unsaturated polyester										
Ortho-phthalate	100–135	50–75	3.2–4.5	1.2–4.0	55–100	80–100	fair	poor	fair	poor
Iso-phthalate	110–140	55–90	3.0–4.0	0.8–2.8	100–125	100–130	good	fair	good	poor/fair
Modified bisphenol type	125–135	65–75	3.2–3.8	0.9–2.6	130–180	130–180	very good	fair	good	fair/good
Epoxy (bisphenol)										
Aliphatic polyamine cure	85–125	50–70	3.5	1.0–3.5	60–90	100	good	fair/good	fair/good	fair/good
Boron trifluoride complex	110	85	3.0–4.0	1.0–2.5	120–190	90–150	good	fair/good	good	good
Aromatic amine cure	80–130	60–75	3.0–3.5	1.5–3.5	85–170	120–180	excellent	good	fair/good	good
Aromatic anhydride cure	90–130	80–105	2.6–3.5	2.0–2.5	130–200	150–220	poor/fair	poor/fair	good	poor
Vinyl ester	110–130	70–85	3.3	1.0–4.0	90–125	150–180	good	fair/good	good	good
Polyimide	75–130	50–120	3.1–4.7	2.0–3.5	250–360	250–400	low	—	—	low
Friedel-Crafts	110–120	95–110	4.1	1.5–3.0	160–240	150–300	excellent	good	good	fair/good
Phenolic/furane	100–120	60–75	2.5–3.5	0.5–1.0	180–220	250–300	good	excellent	good	poor
Silicone						250–300	good	poor	fair/good	poor/fair

Note: The data given in this table is to be regarded as indicative only of general resin performance in the classes shown. Departures from standard materials in resins, crosslinking agent, cures, etc., can produce large property changes.

5.5 EXTERNAL COATINGS

One of the more reasonable approaches mentioned by the industrial POCs was the use of a shrink-wrap overpackage on the current DS2 cans. Shrink-wrapping has the advantages of simplicity and low-cost, but may have limited effectiveness. Shrink-wrapping uses polyethylene films which are loosely wrapped around the container and then are heat-sealed to conform to the package at a temperature of 300°F (150°C) for about 10 seconds (6 mil polyethylene film) (Ref. 9). A thinner film might be a viable option, as the short time in the hot oven will not cause enough heat transfer to present a fire or explosion risk with the DS2 (flashpoint 160°F).

The major drawbacks of shrink-wrapping are the potential increases in cost due to changes/additions to the production line, and potentially limited effectiveness. While shrink-wrapping is a simple task and is amenable to incorporation in an assembly line, adding the process to the production line represents an added cost.

As with any external weatherproofing technique, the effectiveness of shrink-wrapping will depend on the treatment of the finished package. Any weakness in an external coating will allow water to penetrate, promoting the corrosion of active sites, such as the welds or solder joints, where differing metals and alloys can undergo galvanic activity, eventually resulting in penetration and loss of seal integrity.

Rough handling of DS2 cans already has resulted in a history of disruption of the (older) alkyd enamel and (more recently) polyurethane camouflage coatings, leading eventually to seepage of the DS2. A shrink-wrap overpack may reduce this problem, but also may not solve it. Polyethylene films get brittle during long-term environmental exposure, and would eventually flake off. The potential increase in shelf life of the DS2 container may offset the additional cost of producing the shrink-wrapped containers, and may result in a lower life-cycle cost, but the task team is unable to quantify any cost-savings.

One company suggested the use of a sprayable elastomeric coating over the current paint. The formulation could be polyurethane-based (one-component or multi-component) or based on other formulations. A sprayable elastomer would be more resistant to damage from rough-handling than the current MILSPEC polyurethane-based CARC, which tends to be brittle. Testing would be required to determine compatible overcoating formulations.

A few companies indicated that a second coat of a good paint could solve the problem. Some paints recommended were epoxy paints or polyurethane paints. A comparison of a list of coatings suitable for atmospheric service (Ref. 10) is presented at Appendix G. However, since the containers are currently painted with a MILSPEC polyurethane paint, this does not seem to offer a viable solution. The problem starts with scratches or nicks to the paint, as previously mentioned, and a second coat of paint or touch-up paint would not be highly effective in preventing corrosion under the typical rough-handling environment to which the containers are subjected.

5.6 SOLDERS

Most cans produced commercially are sealed with a Lead-Tin-Bismuth solder. These solders are inexpensive and are easily worked, as they soften in the 260-375°F range (depending on the exact composition). The following table presents data on these low-melting point solders (Ref. 11):

Table 2. Melting Point Solders

(From N.B.S. Circular 492)

Nominal Composition, Weight Percent			Liquids Temperature °F
Pb	Sn	Bi	
25	25	50	266
50	37.5	12.5	374
25	50	25	336

One POC suggested switching from the commonly used low melting point solders to a silver solder. Data on the various silver solders is presented below (Ref. 11):

Table 3. Brazing Filler Metals (Solders)

AWS-ASTM Classification	Solidus, °F	Liquidus, °F	Brazing Temperature Range, °F	Ag	Al	As	Au	B	Be	Bi	C	Cd	Cr	Cu	Fe	Li	Mg	Mn	Ni	P	Pb	Sb	Si	Sn	Ti	Zn	Other Each	Other Total	AWS-ASTM Classification
SILVER																													
BAg-1	1125	1145	1145-1400	44-46								23-25		14-16												14-18		0.15	BAg-1
BAg-1a	1160	1175	1175-1400	49-51								17-19		14.5-16.5												14.5-18.5		0.15	BAg-1a
BAg-2	1125	1295	1295-1550	34-36								17-19		25-27												19-23		0.15	BAg-2
BAg-3	1170	1270	1270-1500	49-51								15-17		14.5-16.5					2.5-3.5							13.5-17.5		0.15	BAg-3
BAg-4	1240	1435	1435-1650	39-41										29-31					1.5-2.5							26-30		0.15	BAg-4
BAg-5	1250	1370	1370-1550	44-46										29-31												23-27		0.15	BAg-5
BAg-6	1270	1425	1425-1600	49-51										33-35												14-18		0.15	BAg-6
BAg-7	1145	1205	1205-1400	55-57										21-23										4.5-5.5		15-19		0.15	BAg-7
BAg-8	1435	1435	1435-1650	71-73										Bal.														0.15	BAg-8
BAg-8a	1410	1410	1410-1600	71-73										Bal.		0.15-0.3												0.15	BAg-8a
BAg-13	1325	1575	1575-1775	53-55										Bal.												4.0-6.0		0.15	BAg-13
BAg-18	1115	1125	1325-1550	59-61										Bal.						0.025				9.5-10.5				0.15	BAg-18
BAg-19	1435	1635	1610-1800	92-93										Bal.		0.15-0.3												0.15	BAg-19

The advantage of the use of silver solder is that it is more "noble" (less reactive) than the low melting point solders, and would last longer under environmental exposure. The disadvantages are the increased cost (about $0.10 of solder per can for silver solder) and the higher working temperature required.

The requirement for a higher working temperature for silver solder could pose some problems on the production line. The higher temperature required could pose a greater risk of flashing the components of DS2. However, there are techniques available which provide local heating quickly enough to successfully solder the can without significantly increasing the temperature of the bulk liquid for the larger containers. The small (1-1/3 quart) container will present the greatest hazard. Likewise, the heat transferred to the container will increase the pressure inside, potentially causing some deformation of the container, especially the small can.

6. CONCLUSIONS

In general, contacting hazardous waste management companies was not useful for this task. Regulatory strictures prevent the companies from storing wastes for longer than one year, and economics dictate that the faster the incinerator destroys the liquid wastes the quicker the company realizes a return on its investment. Storing caustic liquid wastes for long periods just doesn't make sense.

Federal regulations, issued by the Department of Transportation, dictate the types of containers to be used for specific chemicals and few, if any, companies in the U.S. make any improvements to these DOT-specified containers beyond painting them.

Stainless steel was frequently recommended as the best option for a non-corroding container. Stainless steel would be able to meet all the rough-handling and storage requirements needed, but would be expensive for use as a disposable can.

Containers made from a variety of polymers were suggested as replacements for carbon steel or Terne plate. Polyethylene and polypropylene are commonly used for chemical storage and overpacking, but may not perform well over the longer periods demanded by the Army. Fluorinated polymers may be useful, and should be explored further. Another possible candidate is PEEK.

The use of a polyethylene-film shrink wrap would add a water-repellent barrier to the outside of the DS2 container and could extend the shelf life of the can significantly. However, as with paint, rough handling could cause punctures or tears in the shrink wrap which would negate its effectiveness.

An elegant solution to the problem with corrosion of the solder seals is to change from the lead-tin-bismuth (Pb-Sn-Bi) solder currently used to a more noble, and more expensive, silver solder. Silver solder would necessitate changes to the production line and may create a hazard because of the higher operating temperature required.

While not specifically required in this survey, some potentially beneficial information concerning costs was collected. These data are presented in Appendix H.

7. RECOMMENDATIONS

The following techniques are recommended as potential improvements to the Technical Data Package (TDP) for the cans for DS2:

- Use a silver solder to seal the end caps.
- Apply an elastomeric sealant.
- Apply a shrink-wrap outer coating.
- Investigate the use of PEEK or fluorocarbons for containers.
- Prevent rough-handling of the cans to avoid scratching the paint.

The use of stainless steel for the can would correct the problem at hand, and may be the ultimate answer. However, the high cost of the can poses a potential obstacle to its adoption. In addition, stainless steel does not accept paint very well, and would be difficult to camouflage.

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APPENDIX A

COMPANIES CONTACTED

ABCO Industries, Inc.
P.O. Box 335
Roebuck, SC 29376
1 (803) 576-6821
Janine Dworley

Air Products and Chemicals, Inc.
Surface Treated Products, Airopak Containers Division
Allentown, PA 18195
1 (800) 247-6725
Laurie Maurer

All-American Environmental Corp
140-53rd Street
Brooklyn, NY 11232
1 (718) 492-7400
Joe Capp

All-Pak, Inc.
2260-T Roswell Drive
Pittsburgh, PA 15205
1 (412) 922-4566
Bill Barger

Allstate Can Corp.
40-T Isabella St.
Clifton, NJ 07012
1 (201) 773-0100
Ron Peppele

American Metal Fab., Inc.
55515 Franklin Industrial Park
Three Rivers, MI 49093
1 (616) 279-5108
Al West

American Technology and Research Industries, Inc.
1510 SW 17th Street, Dept. RL
Ocala, FL 32674
1 (904) 622-4242

American Science and Technology, Inc.
1 (609) 786-1751
George Lopez

American Waste, Inc.
P.O. Box 306
Maywood, IL 60153
1 (708) 681-3999

Aptus Environmental Services, Inc.
Coffeeville, KS

Ashland Chemical Company, Ind. Chem. and Solvents Div.
P.O. Box 2219
Columbus, OH 43216
1 (614) 889-3333
Ron Cimmino

B.E.S. Environmental Specialists
82-86 Boston Hill Road
Larksville, PA 18651

BCM Engineers
1 Plymouth Meeting, Suite 506
Plymouth Meeting, PA 19462
1 (215) 825-3800

Belmet Products, Inc.
60 Beadel Street
Brooklyn, NY 11222
1 (718) 782-3554
Rich Goss

Bonar Plastics, Inc.
19705 SW Teton Avenue, P.O. Box 487
Tualatin, OR 97062
1 (503) 692-0560
Phil Sargeant

Browning Ferris Industries

By-Products Management of Ohio, Inc.
17879-T St. Clair Avenue
Cleveland, OH 44110
1 (216) 486-9100
Carl Munn

CBI Services, Inc.
St. George Road
Bourbonnais, IL 60914-7001
1 (815) 933-4440
Chuck Bull

Chemarex/Cal Bionuclear Corp
13125 South Broadway
Los Angeles, CA 90061
1 (213) 515-5260
Dr. Ahmed

Chem-Clear
2900-T Broadway Near Independence Rd.
Cleveland, OH 44115

Chemical Waste Management Inc.
3003-T Butterfield Road
Oak Brook, IL 60521
1 (708) 218-1500
Dave McKuehn

Cleveland Steel Containers
350 Mil Street
Quakertown, PA 18951
1 (215) 536-4477
Don Doulan

Coating Systems, Inc.
55 Crown Street, Dept. TR
Nashua, NH 03060
1 (603) 883-0553
Aram Jeknavorian

Columbiana Boiler Company
198 West Railroad Street
Columbiana, OH 44408
1 (216) 482-3373
Bill Riddle

Compliance Services, Inc.
Wayne, PA
1 (215) 254-0842
Russ Phifer

Consolidated Container Corp.
735 N. 3rd Street, Dept. 110
Minneapolis, MN 55401
1 (612) 338-0753
Joel Wirth

Container Products, Inc.
7838 Iron Street, P.O. Drawer 158
Masury, OH 44438
1 (216) 448-6841
Robert Beaudrie

Container Research Corp.
Hollow Hill Road
Glen Riddle, PA 19037
1 (215) 459-2160
Chris Leiser

Crown Anderson, Inc.
306 Dividend Drive
Peachtree City, GA 30269
1 (800) 241-5424

Crown Rotational Molded Products, Inc.
P.O. Drawer 577
Marked Tree, AR 72365
1 (501) 358-3400
Jack Hendricks

Cyprus Environmental Industries, Inc.
300 Crescent Court Ste 1105
Dallas, TX 75201
1 (214) 871-2299
Bill Conley

DAS Environmental, Inc.
2516 E. Ontario Street, Dept. MS
Philadelphia, PA 19134
1 (215) 739-3445
Wayne Chapman

Dipseal Plastics, Inc.
2311-23D Avenue
Rockford, IL 61104
1 (800) 634-7821
Scott Platt

Douglass, Gordon, and Associates
121 Berwick Heights Road, P.O. Box 496-A
East Stroudsberg, PA 18301
1 (717) 476-6600
Mr. Douglass

ECOVA
12790 Merit Drive Suite 220-A
Dallas, TX 75251
1 (214) 238-0600
Arnie Sugar

ETI Group Companies of North America
P.O. Box 2286
Denver, CO 80201

Ellisco, Inc.
4010 N. American Street
Phildelphia, PA 19140
1 (215) 223-3500
Peter Riley

Ensign Bickford Haz-Pros, Inc.
656 Hopmeadow Street
Simsbury, CT 06070
1 (203) 651-2603
John Fowler

Envirite
600-T West Germantown Pike
Plymouth Meeting, PA 19462
1 (215) 828-8655
Bill McTige

Environmental Contracting and Supply Co.
P.O. Box 338-T
La Grange, IL 60525
1 (708) 579-1104
Dick Halm

Environmental Elements Corp.
3700 Kopper Street, P.O. Box 1318
Baltimore, MD 21203
1 (301) 368-7000
Werner Eichanmer

Environmental Technologies International
P.O. Box 2841
Reno, NV 89505
1 (702) 322-1164

Envirosafe Services, Inc.
115 Gilbralter Road
Horsham, PA 19044

FMP Corp.
250 Risdon Street
Naugatuck, CT 06770
1 (203) 723-5232
Claire Pelgrow

Freund Can Company
167 West 84th Street
Chicago, IL 60620
1 (312) 224-4230
Mr. O'Brien

GSX Chemical Services, Inc.
P.O. Box 21079, Dept. TR
Columbia, SC 29221
1 (803) 798-2993

HAZMAT Training, Information and Services, Inc.
6480 Dobbin Road Columbia Center
Columbia, MD 21045
1 (301) 964-0940

HEMC Environmental Management
2681-T Dow Avenue, Unit No. C-1
Anaheim, CA 92680
1 (714) 364-3005

Hardigg Industries, Inc.
393 N. Main Street
South Deerfield, MD 01373
Dave Macdonald

Hart Environmental Management Corp.
530 Fifth Aveneue, Dept. TR
New York, NY 10036
1 (212) 447-1480
June Williams/Fred Hart

Helios Container Systems, Inc.
315-T Fairbanks Street
Addison, IL 60101
1 (708) 529-7590
Barbara Donner

Hitech Research and Development, Inc.
8625-T 68th Street, S.E., P.O. Box 998
Calgary, Alberta, Canada

Hudson Tool and Dye Company
18 Malvern Street
Newark, NJ 07105
1 (201) 589-1800
Bill Cuthbert

Hunter Drums LTD.
1121 Pioneer Road
Burlington, Ontario, Canada
1 (416) 333-1145
Wayne Gow

Inland Pollution Services, Inc.
646-T Garden
Elizabeth, MJ 07202
1 (201) 353-5544
John Guy

International Technology Corp.
23456-T Hawthorne Bvld.
Torrance, CA 90505
1 (213) 378-9933
Laura Johnston/Mr. Soesbe

J&B Systems
P.O. Box 245
Milford, OH 45150
1 (513) 732-2000

JMH Industries, Inc.
217-219 Versaw Ct.-T P.O. Box 930-T
Berthoud, CO 80513
1 (303) 532-4040
Kaupp, C.B. and Sons, Inc.
12 Newark Way
Maplewood, NJ 07040
1 (201) 761-4000
Clem Kaupp, Jr.

Kosempel Mfg. Co.
3700 Main Street
Phildelphia, PA 19134
1 (215) 533-7110
John Solheim

M & S Engineering and Mfg. Company, Inc.
95 Rye Street
Broad Brook, CT 06016
1 (203) 627-9396
Sigmuand Koslowski

Maecorp
17450-T S. Halsted Street
Homewood, IL 60430
1 (800) 372-7745
Phil Mazor

Marisol, Inc.
123 Factory Lane
Middlesex, NJ 08846
1 (201) 469-5100

McClain Industries, Inc.
P.O. Box 913
Sterling Heights, MI 48087
1 (405) 691-6311
Jamie Reeves

Melmat, Inc.
1400 W. 240th Street
Harbor City, CA 90710
1 (213) 325-1625
John Mellott

Mid-States Metal Lines, Inc.
4001-T E. 137th Terr.
Grandview, MO 64030
1 (816) 765-5444
Les Martin

Mirax Chemical Products, Inc.
Metal Containers Division
4997 Fyler Avenue
St. Louis, MO 63139
1 (314) 752-1500
Oliver Clert

Mutual Stamping and Manfacturing Co.
241 Shetland Road, P.O. Box 656-T
Fairfield, CT 06431
1 (203) 877-3933
Bob Fox

National Packaging Services, Inc.
34-40 Laurel Hill Blvd.
Maspeth, NY 11378
1 (718) 786-6343
Bob Strasser

OH Materials Corp.
P.O. Box 551 Dept. TR
Findlay, OH 45839
1 (419) 423-3526
Marsha Robinson

PDI Plastidip International
P.O. Box 130
Circle Pines, MN 55014
1 (612) 785-2156
Chuck Nelson

Pacific Rim Packaging Corp.
801-T Chesley Avenue, P.O. Box 4026
Richmond, CA 94804-0026
1 (415) 234-7114
Glen Langstaff

Packaging Specialties, Inc.
9522 Richmond Avenue
Cleveland, OH 44105
1 (216) 271-7988
Paul Libby

Potomac Metal and Supply, Inc.
Route 51, Box 1415
Cumberland, MD 21502
1 (301) 722-4030

Process Technology Co.
1 (800) 782-0841

Quick Draw and Machining, Inc.
4869-T McGrath Street
Ventura, CA 93003
1 (805) 644-7882
Mr. Ward-Llwewllyn

Rack Engineering Company
299-T S. 7th Street
Connellsville, PA 15425
1 (412) 628-8400
Frank Minor

Rem-Tech
Loiseberry, PA
1 (717) 938-6745
Errol Fletcher

Robertson Can Company
16 N. Lowry Avenue
Springfield, OH 45501
1 (513) 323-3747
Mr. Robertson

Rochelle Steel Fabricating, Inc.
Rt. 251 South
Rochelle, IL 61068
1 (815) 562-7805
Tom Hart

Rollings Environmental Services(DE), Inc.
One Rollins Plaza, P.O. Box 2349-T
Wilmington, DE 19899
1 (302) 479-2700
Fred Gerdes

Roy F. Weston, Inc.
Weston Way
West Chester, PA 19380
1 (215) 692-3030
Joel Carmazine

Safety Shield Corp.

Scientific Plastics CO., Inc.
550 Elizabeth Street
P.O. Box 642
Waukesha, WI 53187
Mr. Portz

Skolnik Industries, Inc.
4900 S. Kilbourn Ave.
Chicago, IL 60632
1 (312) 735-0700
Dan Abram

Sommer Metalcraft Corp.
500 Poston Drive
Crawfordsville, IN 47933
1 (800) 654-3124
Greg Bryant
Sonoco Plastic Drum
1225-T Davies Street
Lockport, IL 60441
1 (815) 838-7210

Statewide Environmental Services
1 (415) 865-2978
Dick Clark

Staver Company, Inc.
45-T Saxon Avenue
Bay Shore, NY 11706
1 (516) 666-8000
J.B. Lazarus

Steel King Industries, Inc.
2700 Chamber Street, Dept. KG
Stevens Point, WI 54481
1 (715) 341-3121

Steeltin Can Corp.
1101 Todds Lane
Baltimore, MD 21237
1 (301 686-6363
Rich DiMarcantonio

Stout Environmental
R.R. 4 Box 140 N. Woodbury Road
Sewell, NJ 08080

TDP Industries, Inc.
603A Airport Blvd.
Doylestown, PA 18901
1 (215) 345-8687
Ray Miller

TRC Companies, Inc.
800-T Conneticut Blvd.
East Hartford, CT 06108
1 (203) 289-8631
George McKenney

Thermal Oxidation Corp.
Roebuck, SC 29376
1 (803) 576-1085
Diane Prioletti

U.S. Ecology

Van Leer Corp.
1 (800) 323-3151

Washington Aluminum Company
Knecht Avenue
Baltimore, MD 21229
1 (301) 242-1000
Stephanie Coulteau

Waste Research and Reclamation Company, Inc.
Industrial Center Highway 93
Eau Claire, WI 54701
1 (715) 836-8760
Jack Viesezak

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APPENDIX B

Extract from 49 CFR 173
and
Packaging Instructions 809 and 813

discs having a ⅛-inch breather hole in the center thereof.

(6) Specification MC 310, MC 311, or MC 312 (§ 178.343 of this subchapter). Cargo tanks. Bottom outlets are authorized if they meet the requirements of § 178.343-5 of this subchapter.

(7) Spec. 60 (§ 178.255 of this subchapter). Portable tanks.

(8) Specification IM 101 portable tanks (§§ 178.270, 178.271 of this subchapter) are authorized under conditions specified in the IM Tank Table.

(49 U.S.C. 1803, 1804, 1808; 49 CFR 1.53, App. A to Part 1)

[29 FR 18725, Dec. 29, 1964, as amended by Order 71, 31 FR 9070, July 1, 1966; Order 73, 32 FR 3456, Mar. 2, 1967. Redesignated at 32 FR 5606, Apr. 5, 1967]

EDITORIAL NOTE: For Federal Register citations affecting § 173.248, see the List of CFR Sections Affected appearing in the Finding Aids section of this volume.

§ 173.249 Alkaline corrosive liquids, n.o.s.; alkaline liquids, n.o.s.; alkaline corrosive battery fluid; potassium fluoride solution; potassium hydrogen fluoride solution; sodium aluminate, liquid; sodium hydroxide solution; potassium hydroxide solution.

(a) Alkaline corrosive liquids, n.o.s.; alkaline liquids, n.o.s.; alkaline corrosive battery fluid; potassium fluoride solution; potassium hydrogen fluoride solution; sodium aluminate, liquid; sodium hydroxide solution and potassium hydroxide solution, when offered for transportation by carriers by rail freight, highway, or water must be packed in specification containers of a design and constructed of materials that will not react dangerously with or be decomposed by the chemical packed therein as follows:

(1) In containers prescribed in § 173.245.

(2) Specification 15A, 15B, 15C, 16A, 19A, or 19B (§§ 178.168, 178.169, 178.170, 178.185, 178.190, 178.191 of this subchapter). Wooden boxes with inside glass or earthenware containers not over 2 gallons each, or with metal containers, not over 5 gallons each.

(3) Specification 5 (§ 178.80 of this subchapter) metal drums. Openings must not exceed 2.3 inches in diameter.

(4) [Reserved]

(5) Specification 103,[1] 103W, 103A,[1] 103AW, 103B,[1] 103BW, 104,[1] 104W, 105A100,[1] 105A100W, 111A60F1, 111A60W1, 111A60W2, 111A100F2, 111A60W5, or 111A100W4 (§§ 179.100, 179.101, 179.200, 179.201 of this subchapter). Tank cars.

(6) Specification MC 303, MC 310, MC 311 or MC 312 (§ 178.343 of this subchapter). Cargo tanks. Specification MC 303 is authorized for alkaline corrosive liquids, n.o.s., and alkaline liquids, n.o.s. only and is not authorized for transportation by water: Bottom outlets are authorized if they meet the requirements of § 178.343-5 of this subchapter.

(7) Specification 57 or 60 (§§ 178.251, 178.253, 178.255 of this subchapter). Portable tanks. Specification 57 portable tank not authorized for transportation by water.

(8) Spec. 12B (§ 178.205 of this subchapter). Fiberboard boxes with glass inside containers of not over 16 ounces capacity each.

(9) [Reserved]

(10) Spec. 12B (§ 178.205 of this subchapter). Fiberboard boxes, with not more than one glass inside container not over 1 gallon capacity containing sodium hydroxide solution not over 25 percent strength and packed in a strong fiberboard box. Dry chemicals for photographic development process not classed as dangerous articles, contained in suitable inside packages, may be packed in the same outside box. The marking requirements of § 172.312 of this subchapter, shall not apply.

(11) Spec. 29 (§ 178.226 of this subchapter). Mailing tubes, with not more than one inside polyethylene bottle not over 1-quart capacity each.

(12) Spec. 1H (§ 178.13 of this subchapter). Metal crate with inside polyethylene container Spec. 2T (§ 178.21 of this subchapter).

(13) Specification 12B (§ 178.205 of this subchapter). Fiberboard box with inside metal containers. Not more than four 1-gallon or six 1-quart containers may be packed in each box. Maximum gross weight may not

[1]The use of existing tanks authorized but new construction not authorized.

exceed 65 pounds and the completed package must meet the test requirements of § 178.210-10 of this subchapter.

(14) Specification IM 101 portable tanks (§§ 178.270, 178.271 of this subchapter) are authorized under conditions specified in the IM Tank Table.

(b) The hazardous materials named in paragraph (a) of this section, when offered for transportation by aircraft, must be packaged as follows (also authorized for transportation by rail freight, highway or water):

(1) In packagings as prescribed in paragraphs (a)(8), (10), and (11) of this section and § 173.245(a)(7) and (12).

(2) Spec. 5 or 5A (§ 178.80 or 178.81 of this subchapter). Metal barrels or drums, capacity not exceeding 10 gallons, with openings not exceeding 2.3 inches in diameter.

(3) Specification 15A, 15B, 15C, 16A, 19A, or 19B (§§ 178.168, 178.169, 178.170, 178.185, 178.190, 178.191 of this subchapter). Wooden boxes with inside glass or earthenware containers not over 1-gallon each, or with inside metal cans, not over 5 gallons each.

(c) Limited quantities of alkaline corrosive liquids, n.o.s., alkaline liquids, n.o.s., alkaline corrosive battery fluids, and liquid sodium aluminate in inside packagings of not more than 8 fluid ounces capacity each, packed in strong outside packagings, and cushioned with absorbent material in sufficient quantity to completely absorb liquid contents in the event of breakage, are excepted from labeling (except labeling is required for transportation by air) and specification packaging requirements of this subchapter. In addition, shipments are not subject to Subpart F of Part 172 of this subchapter, to Part 174 of this subchapter except § 174.24 and to Part 177 of this subchapter except § 177.817.

(d) Special exceptions for shipment of certain alkaline in the ORM-D class are provided in Subpart N of this part.

(49 U.S.C. 1803, 1804, 1808; 49 CFR 1.53, App. A to Part 1)

[29 FR 18725, Dec. 29, 1964. Redesignated at 32 FR 5606, Apr. 5, 1967]

EDITORIAL NOTE: For Federal Register citations affecting § 173.249, see the List of CFR Sections Affected appearing in the Finding Aids section of this volume.

§ 173.249a Cleaning compound, liquid; coal tar dye, liquid; dye intermediate, liquid; mining reagent, liquid; and textile treating compound mixture, liquid.

(a) A liquid cleaning compound subject to this section must not contain any corrosive material specifically named in § 172.101 of this subchapter, except phosphoric acid, acetic acid, and not over 15 percent sodium or potassium hydroxide.

(b) A liquid dye intermediate is a ring compound, containing amino, hydroxy, sulfonic acid, or quinone group or a combination of these groups, used in the manufacture of dyes, and not otherwise specifically named in § 172.101 of this subchapter.

(c) A liquid textile treating compound mixture is a mixture used to treat woven, knit or otherwise manufactured fabrics. It does not include mixtures used only to treat fibers, filaments, or yarn used in making the fabric.

(d) Liquid coal tar dye, liquid cleaning compound, liquid dye intermediate liquid mining reagent, and liquid textile treating compound mixture must be packaged as follows:

(1) In specification packagings as prescribed in § 173.245.

(2) In packagings meeting all of the specific requirements prescribed in § 173.245 including packaging type and quantity limitations for inside packagings. The packagings are not required to meet the detailed specification requirements of Part 178 of this subchapter except that size and weight limitations for package types as prescribed in Part 178 may not be exceeded. Not authorized for shipment by aircraft.

(3) Removable (open) head fiber drum lined or coated on the inside with a plastic material, not over 55-gallon capacity. Not authorized for shipment by aircraft.

(4) Removable (open) head metal drum, not over 55-gallon capacity. Not authorized for shipment by aircraft.

(5) Removable (open) head polyethylene drum, not over 6.5-gallon capacity. Not authorized for shipment by aircraft.

The general packing requirements of Part 3, Chapter 1 must be met.

Single packagings are not permitted.

Combination packagings:

Inner

UN No.	*Glass or earthenware IP.1 (L)*	*Plastic IP.2 (L)*	*Metal (not aluminium) IP.3 (L)*	*Aluminium IP.3A (L)*	*Glass ampoule IP.8 (L)*	*Particular packing requirements*
1715	1	1	1	1	0.5	2,5,7,13
1719	1	1	1	No	0.5	
1722	1	1	No	No	0.5	13
1739	1	1	No	No	0.5	13
1740	No	1	1	No	No	
1744	1	1	No	No	0.5	2,13
1750	1	1	1	No	0.5	5,13
1754	1	1	1	1	0.5	2,7,13
1758	1	1	1	No	0.5	2,5,13
1760	1	1	1	No	0.5	2,13
1764	1	1	1	No	0.5	2,5,13
1765	1	1	1	No	0.5	2,5,13
1768	No	1	1	No	No	2,5
1774	1	1	No	No	0.5	
1775	1	1	1	No	0.5	2,5,21
1776	1	1	1	No	0.5	2,5,21
1777	1	1	1	1	0.5	2,5,7,13,21
1778	1	1	1	No	0.5	2,5,21
1782	1	1	1	No	0.5	2,5,21
1786	No	1	1	No	No	2,5
1787	1	1	No	No	0.5	2,13
1788	1	1	No	No	0.5	2,13
1789	1	1	No	No	0.5	2,13
1790	No	1	1	No	No	2,5
1791	1	1	1	No	0.5	5
1796	1	No	1	No	0.5	5,13
1798	1	No	No	No	0.5	13
1803	1	1	No	No	0.5	
1811	No	1	1	No	No	
1814	1	1	1	No	0.5	
1818	1	1	No	No	0.5	2,13
1824	1	1	1	No	0.5	
1826	1	No	1	No	0.5	5,13
1828	1	1	1	1	0.5	5,7,13
1830	1	1	1	No	0.5	5,13
1831	1	1	1	No	0.5	2,5,13
1834	1	1	1	1	0.5	2,5,13
1836	1	1	1	No	0.5	2,7,13
1908	1	1	1	No	0.5	2,13
1940	1	1	1	No	0.5	5
2031	1	No	No	No	0.5	13
2032	1	No	No	No	0.5	13
2240	1	1	1	No	0.5	2,5,13
2258	1	1	1	No	0.5	2,13
2308	1	1	1	No	0.5	2,5,13
2438	1	1	1	No	0.5	2,5,13
2439	No	1	1	No	No	
2444	1	1	1	No	0.5	2,5,13
2502	1	1	1	No	0.5	2,5,13
2564	1	1	1	No	0.5	2,5,13
2604	1	1	1	1	0.5	
2677	1	1	1	No	0.5	
2679	1	1	1	No	0.5	

809 PACKING INSTRUCTION 809 *(cont.)* 809

UN No.	*Glass or earthenware IP.1 (L)*	*Plastic IP.2 (L)*	*Metal (not aluminium) IP.3 (L)*	*Aluminium IP.3A (L)*	*Glass ampoule IP.8 (L)*	*Particular packing requirements*
2681	1	1	1	No	0.5	
2692	1	1	1	No	0.5	2,5,13
2699	1	1	1	No	0.5	5,13,21
2734	1	1	1	No	0.5	2,13
2735	1	1	1	No	0.5	2,13
2789	1	1	1	1	0.5	2,5,7,13
2790	1	1	1	1	0.5	2,5,7,13
2796	1	1	1	No	0.5	5,13
2797	1	1	1	No	0.5	
2817	No	1	1	No	No	
2837	1	1	1	No	0.5	
2879	1	1	1	No	0.5	2,5,13
2920	1	1	1	No	0.5	2,13
2922	1	1	1	No	0.5	2,13

Outer

Steel drum – 1A2
Aluminium drum – 1B2
Steel jerrican – 3A2
Plywood drum – 1D
Fibre drum – 1G
Plastic drum – 1H2
Plastic jerrican – 3H2
Wooden box – 4C1, 4C2
Plywood box – 4D
Reconstituted wood box – 4F
Fibreboard box – 4G

Particular packing requirements:

2 Plastic inner packagings must be packed in tightly closed metal receptacles before packing in outer packagings.

5 Steel packagings must be corrosion-resistant or with protection against corrosion.

7 When aluminium or aluminium alloys are used they must be resistant to corrosion.

13 Glass inner packagings and glass ampoules must be packed with absorbent material in tightly closed metal receptacles before packing in outer packagings.

21 If free from hydrofluoric acid then glass inner packagings are permitted.

810 PACKING INSTRUCTION 810 810

The general packing requirements of Part 3, Chapter 1 must be met.

Single packagings are not permitted.

Combination packagings:

Inner

Glass or earthenware – IP.1	0.5 kg
Plastic – IP.2	0.5 kg
Metal – IP.3, IP.3A	0.5 kg
Glass ampoule – IP.8	0.5 kg

Outer

Steel drum – 1A2
Aluminium drum – 1B2
Steel jerrican – 3A2
Plywood drum – 1D
Fibre drum – 1G
Plastic drum – 1H2
Plastic jerrican – 3H2
Wooden box – 4C1, 4C2
Plywood box – 4D
Reconstituted wood box – 4F
Fibreboard box – 4G

PACKING INSTRUCTION 813

The general packing requirements of Part 3, Chapter 1 must be met.

Combination packagings:

Inner

UN No.	*Glass or earthenware IP.1 (L)*	*Plastic IP.2 (L)*	*Metal (not aluminium) IP.3 (L)*	*Aluminium IP.3A (L)*	*Glass ampoule IP.8 (L)*	*Particular packing requirements*
1715	2.5	2.5	2.5	2.5	0.5	2,5,7,13
1719	2.5	2.5	2.5	No	0.5	
1724	2.5	2.5	2.5	No	0.5	5
1728	2.5	2.5	2.5	No	0.5	5
1732	2.5	2.5	2.5	2.5	0.5	2,5,7,13,21
1740	No	2.5	2.5	No	No	
1747	2.5	2.5	2.5	No	0.5	5
1750	2.5	2.5	2.5	No	0.5	5,13
1753	2.5	2.5	2.5	No	0.5	5
1762	2.5	2.5	2.5	No	0.5	5
1763	2.5	2.5	2.5	No	0.5	5
1764	2.5	2.5	2.5	No	0.5	2,5,13
1765	2.5	2.5	2.5	No	0.5	2,5,13
1766	2.5	2.5	2.5	No	0.5	5
1767	2.5	2.5	2.5	No	0.5	5
1768	No	2.5	2.5	No	No	2,5
1769	2.5	2.5	2.5	No	0.5	5
1771	2.5	2.5	2.5	No	0.5	5
1775	2.5	2.5	2.5	No	0.5	2,5,21
1776	2.5	2.5	2.5	No	0.5	2,5,21
1778	2.5	2.5	2.5	No	0.5	2,5,21
1781	2.5	2.5	2.5	No	0.5	5
1782	2.5	2.5	2.5	No	0.5	2,5,21
1784	2.5	2.5	2.5	No	0.5	5
1787	2.5	2.5	No	No	0.5	2,13
1788	2.5	2.5	No	No	0.5	2,13
1789	2.5	2.5	No	No	0.5	2,13
1790	No	2.5	2.5	No	No	2,5
1791	2.5	2.5	2.5	No	0.5	5
1796	2.5	No	2.5	No	0.5	5,13
1799	2.5	2.5	2.5	No	0.5	5
1800	2.5	2.5	2.5	No	0.5	5
1801	2.5	2.5	2.5	No	0.5	5
1802	2.5	2.5	No	No	0.5	
1803	2.5	2.5	No	No	0.5	
1804	2.5	2.5	2.5	No	0.5	5
1808	2.5	2.5	2.5	No	0.5	2,5,13
1809	2.5	2.5	2.5	No	0.5	5,13
1810	2.5	2.5	2.5	No	0.5	5
1811	No	2.5	2.5	No	No	
1814	2.5	2.5	2.5	No	0.5	
1816	2.5	2.5	2.5	No	0.5	5
1818	2.5	2.5	No	No	0.5	2,13
1824	2.5	2.5	2.5	No	0.5	
1826	2.5	No	2.5	No	0.5	5,13
1830	2.5	2.5	2.5	No	0.5	5,13
1832	2.5	2.5	2.5	No	0.5	5,13
1837	2.5	2.5	2.5	No	0.5	5,13
1838	2.5	2.5	No	No	0.5	2,13
1906	2.5	2.5	2.5	No	0.5	5,13
1908	2.5	2.5	2.5	No	0.5	2,13
1940	2.5	2.5	2.5	No	0.5	

earthenware UN No.	*Glass or Plastic* *IP.1* *(L)*	*aluminium)* *IP.2* *(L)*	*Metal (not Aluminium* *IP.3* *(L)*	*ampoule* *IP.3A* *(L)*	*Glass Particular* *IP.8* *(L)*	*packing requirements*
2031	2.5	2.5	No	No	0.5	2,13
2258	2.5	2.5	2.5	No	0.5	2,13
2308	2.5	2.5	2.5	No	0.5	2,5,13
2435	2.5	2.5	2.5	No	0.5	5
2438	2.5	2.5	2.5	No	0.5	2,5,13
2439	No	2.5	2.5	No	No	
2443	2.5	2.5	2.5	No	0.5	2,5,13
2502	2.5	2.5	2.5	No	0.5	
2564	2.5	2.5	2.5	No	0.5	2,5,13
2672	5	5	10	No	0.5	
2677	2.5	2.5	2.5	No	0.5	
2679	2.5	2.5	2.5	No	0.5	
2681	2.5	2.5	2.5	No	0.5	
2789	2.5	2.5	2.5	2.5	0.5	2,5,7,13
2790	2.5	2.5	2.5	2.5	0.5	5,7,13
2796	2.5	2.5	2.5	No	0.5	5,13
2797	2.5	2.5	2.5	No	0.5	
2817	No	2.5	2.5	No	No	
2837	2.5	2.5	2.5	No	0.5	

Outer

Steel drum – 1A2
Aluminium drum – 1B2
Steel jerrican – 3A2
Plywood drum – 1D
Fibre drum – 1G
Plastic drum – 1H2
Plastic jerrican – 3H2
Wooden box – 4C1, 4C2
Plywood box – 4D
Reconstituted wood box – 4F
Fibreboard box – 4G

Single packagings:

UN No.	*Steel drums 1A1 and cylinders**	*Aluminium drums 1B1*	*Steel jerricans 3A1*	*Plastic drums 1H1*	*Plastic jerricans 3H1*	*Composites (plastic) – all*	*Particular packing requirements*
1715	Yes	Yes	Yes	Yes	Yes	Yes	5,7
1719	Yes	No	Yes	Yes	Yes	Yes	
1724	Yes	No	Yes	No	No	Yes	5
1728	Yes	No	Yes	No	No	Yes	5
1732	Yes	Yes	Yes	No	No	Yes	5,7
1740	Yes	No	Yes	Yes	Yes	Yes	
1747	Yes	No	Yes	No	No	Yes	5
1750	Yes	No	Yes	Yes	Yes	Yes	5
1753	Yes	No	Yes	No	No	Yes	5
1762	Yes	No	Yes	No	No	Yes	5
1763	Yes	No	Yes	No	No	Yes	5
1764	Yes	No	Yes	Yes	Yes	Yes	5
1765	Yes	No	Yes	Yes	Yes	Yes	5
1766	Yes	No	Yes	No	No	Yes	5
1767	Yes	No	Yes	No	No	Yes	5
1768	Yes	No	Yes	No	No	Yes	5
1769	Yes	No	Yes	No	No	Yes	5
1771	Yes	No	Yes	No	No	Yes	5
1775	Yes	No	Yes	Yes	Yes	Yes	5
1776	Yes	No	Yes	Yes	Yes	Yes	5
1778	Yes	No	Yes	Yes	Yes	Yes	5
1781	Yes	No	Yes	Yes	Yes	Yes	5
1782	Yes	No	Yes	Yes	Yes	Yes	5
1784	Yes	No	Yes	No	No	Yes	5
1787	No	No	No	No	No	Yes	
1788	No	No	No	No	No	Yes	
1789	No	No	No	Yes	Yes	Yes	
1790	Yes	No	Yes	Yes	Yes	Yes	5
1791	Yes	No	Yes	Yes	Yes	Yes	5
1796	Yes	No	Yes	No	No	No	5
1799	Yes	No	Yes	No	No	Yes	5
1800	Yes	No	Yes	No	No	Yes	5

* Cylinders must be as permitted in Packing Instruction 200

UN No.	*Steel drums 1A1 and cylinders**	*Aluminium drums 1B1*	*Steel jerricans 3A1*	*Plastic drums 1H1*	*Plastic jerricans 3H1*	*Composites (plastic) — all*	*Particular packing requirements*
1801	Yes	No	Yes	No	No	Yes	5
1803	No	No	No	No	No	Yes	
1804	Yes	No	Yes	No	No	Yes	5
1808	Yes	No	Yes	Yes	Yes	Yes	5
1809	Yes	No	Yes	Yes	Yes	Yes	5
1810	Yes	No	Yes	Yes	Yes	Yes	5
1811	Yes	No	Yes	Yes	Yes	Yes	
1814	Yes	No	Yes	Yes	Yes	Yes	
1816	Yes	No	Yes	No	No	Yes	5
1818	No	No	No	Yes	Yes	Yes	
1824	Yes	No	Yes	Yes	Yes	Yes	
1826	Yes	No	Yes	No	No	No	5
1830	Yes	No	Yes	Yes	Yes	Yes	5
1832	Yes	No	Yes	Yes	Yes	Yes	5
1837	Yes	No	Yes	Yes	Yes	Yes	5
1838	Yes	No	Yes	Yes	Yes	Yes	5
1906	Yes	No	Yes	Yes	Yes	Yes	5
1908	No	No	No	Yes	Yes	Yes	
1940	Yes	No	Yes	Yes	Yes	Yes	
2258	Yes	No	Yes	Yes	Yes	Yes	
2308	Yes	No	Yes	Yes	Yes	Yes	5
2435	Yes	No	Yes	No	No	Yes	5
2438	Yes	No	Yes	Yes	Yes	Yes	5
2439	Yes	No	Yes	Yes	Yes	Yes	
2443	Yes	No	Yes	No	No	Yes	5
2502	Yes	No	Yes	Yes	Yes	Yes	
2564	Yes	No	Yes	Yes	Yes	Yes	5
2672	Yes	No	Yes	Yes	Yes	Yes	
2677	Yes	No	Yes	Yes	Yes	Yes	
2679	Yes	No	Yes	Yes	Yes	Yes	
2681	Yes	No	Yes	Yes	Yes	Yes	
2789	Yes	Yes	Yes	Yes	Yes	Yes	5,7
2790	Yes	Yes	Yes	Yes	Yes	Yes	5,7
2796	Yes	No	Yes	Yes	Yes	Yes	5
2797	Yes	No	Yes	Yes	Yes	Yes	
2817	Yes	No	Yes	Yes	Yes	Yes	
2837	Yes	No	Yes	Yes	Yes	Yes	

Particular packing requirements:

2 Plastic inner packagings must be packed in tightly closed metal receptacles before packing in outer packagings.

5 Steel packagings must be corrosion-resistant or with protection against corrosion.

7 When aluminium or aluminium alloys are used they must be resistant to corrosion.

13 Glass inner packagings and glass ampoules must be packed with absorbent material in tightly closed metal receptacles before packing in outer packagings.

21 If free from hydrofluoric acid then glass inner packagings are permitted.

* Cylinders must be as permitted in Packing Instruction 200

Blank

APPENDIX C

Extract of Information on
Polyetheretherketone (PEEK) Provided by
ICI Advanced Materials/LNP Engineering Plastics
Exton, PA

4. TABLE 1 SUMMARY OF PROPERTIES

Property	ASTM Test Method	Units	PEEK 450G	PEEK 450GL20	PEEK 450GL30	PEEK 450CA30

GENERAL PROPERTIES

Property	ASTM Test Method	Units	PEEK 450G	PEEK 450GL20	PEEK 450GL30	PEEK 450CA30
Form	—	—	Granular	Granular	Granular	Granular
Density (crystalline)	D792	g/cm^3	1.32	1.43	1.49	1.44
(amorphous)			1.265	—	—	—
Colour	—	—	Grey	Brown	Brown	Black
Filler content	—	%	—	20	30	30
Typical level of crystallinity	—	%	35	35	35	35
Processing temperature range	—	°C (°F)	350—380 (660—715)	360—400 (660—715)	370—400 (660—715)	370—400 (660—715)
Water absorption						
24 hours 23°C(73°F)	D570	%	0.5	—	0.11	0.06
Equilibrium 23°C(73°F)	D570	%	0.5	—	—	—
Mould shrinkage	—	%	1.1	0.7*—1.4	0.5	0.1*—1.4

MECHANICAL PROPERTIES

Property	ASTM Test Method	Units	PEEK 450G	PEEK 450GL20	PEEK 450GL30	PEEK 450CA30
Flexural modulus 23°C(73°F)	D790	GPa(psi)	3.66(530,800)	5.88(855,900)	10.31(1495,200)	13.0(1885,400)
Flexural modulus 250°C(480°F)	D790	GPa(psi)	0.3(43,500)	1.2(174,000)	2.3(333,600)	3.6(522,100)
Flexural strength 23°C(73°F)	D790	MPa(psi)	170(24,700)**	192(27,800)	233(33,800)	318(46,100)
Flexural strength 250°C(480°F)	D790	MPa(psi)	12.5(1,800)**	53.7(7,800)**	70.8(10,300)**	105.2(15,200)**
Tensile strength 23°C(73°F)	D638	MPa(psi)	92(Y)(13,300)	123(B)(17,800)	157(B)(22,800)	208(B)(30,200)
Break or yield 250°C(480°F)	D638 Test speed 5 mm/min. (0.2 in/min)	MPa(psi)	12(Y)(1,700)	24(Y)(3,500)	34(B)(4,900)	43(B)(6,200)
Elongation at break 23°C(73°F)	D638 Test speed 5 mm/min (0.2 in/min)	%	50	2.5	2.2	1.3
Elongation at yield 23°C(73°F)	D638 Test speed 5 mm/min (0.2 in/min)	%	4.9	—	—	—
Shear strength (ultimate)	D3846	MPa(psi)	95(13,800)	—	97(14,100)	97(14,100)
Shear modulus 23°C(73°F)	—	GPa(psi)	1.30(188,500)	—	2.40(348,000)	—
Tensile modulus 1% secant 23°C(73°F)	D638	GPa(psi)	3.6(522,100)	7.0(1015,200)	9.7(1406,800)	13(1885,400)
Compressive strength 23°C(73°F): 0°	D695	MPa(psi)	118(17,100)	162(23,500)	215(31,200)	240(34,800)
Compressive strength 23°C(73°F): 90°	D695	MPa(psi)	119(17,300)	134(19,400)	149(21,600)	153(22,200)
Charpy impact strength 23°C(73°F)	BS 2782 Method 351A					
2 mm(0.080 in) notch radius	—	KJ/m^2 (ft-lb/in)	34.9 (6.65)	—	11.3 (0.22)	7.8 (0.15)
0.25 mm(0.010 in) notch radius	—	KJ/m^2 (ft-lb/in)	8.2 (0.15)	—	8.9 (0.17)	5.4 (0.1)
Izod impact strength 23°C(73°F)	D256					
Notched (0.25 mm radius, 2.5 mm depth) (0.010 in radius, 0.100 in depth)	—	J/m (ft-lb/in)	83 (1.55)	88 (1.91)	98 (1.8)	85 (1.6)
Unnotched	—	J/m (ft-lb/in)	No break	673 (12.6)	725 (13.6)	749 (14.0)
Poissons ratio 23°C(73°F)	D638	—	0.42	—	0.45	—
Rockwell hardness						
R scale	D785	—	126	125	124	124
M scale	D785	—	99	102	103	107

THERMAL PROPERTIES

Property	ASTM Test Method	Units	PEEK 450G	PEEK 450GL20	PEEK 450GL30	PEEK 450CA30
Melting point	—	°C(°F)	334(633)	334(633)	334(633)	334(633)
Glass transition temperature	—	°C(°F)	143(289)	143(289)	143(289)	143(289)
Specific heat	—	cal/g °C	0.32	—	—	—
Coefficient of thermal expansion	D696	m/m/°C	47×10^{-6}; 108×10^{-6} at >150°C (>300°F)	24×10^{-6}	22×10^{-6}	15×10^{-6}
Heat distortion temperature 1.82 MPa (264 lbf/in^2)	D648	°C(°F)	160(320)	285(545)	315(600)	315(600)
Thermal conductivity	C177	W/m°C	0.25 - [illegible]	0.41	0.43	0.92
Maximum continuous service temperature (Estimated UL-based test)	—	°C(°F)	250(480)	250(480)	250(480)	250(480)

* Mould shrinkage is dependent on fibre orientation and the lower figure refers to shrinkage in the direction of fibre orientation.

** yield value at > 5% strain

(B) = Break
(Y) = Yield

Property	Test Method	Units	PEEK 450G	PEEK 450GL20	PEEK 450GL30	PEEK 450CA30

FLAMMABILITY PROPERTIES

Flammability Rating						
1.45mm(0.057 in) thick sample	UL94	—	V-0	V-0 ■	V-0	V-0
Limiting Oxygen Index						
0.4 mm(0.015 in) thick sample	ASTM D2863	% O_2	24	—	—	—
3.2 mm(0.125 in) thick sample	ASTM D2863	% O_2	35	—	—	—
Temperature Index						
3.2 mm(0.125 in) thick sample	Based on ASTM D2863	°C(°F)	>325(>615)	—	—	—
Smoke Density (DM)c						
3.2 mm(0.125 in) thick sample: flaming mode	NBS Smoke	—	19	9	—	5
non-flaming mode	Chamber	—	2	2	—	1
1.6 mm(0.062 in) thick sample:	NBS Smoke	—	50	—	—	—
flaming mode non-flaming mode	Chamber	—	5	—	—	—
Time to 90% (DM)c						
3.2 mm(0.125 in) flaming mode thick sample:	NBS Smoke	min	18	19	—	19
3.2 mm(0.125 in) non flaming mode thick sample	Chamber	min	19.6	—	—	—
D(1.5 Min) Value						
Flaming	NBS Smoke	—	0	0	—	0
Non-flaming	Chamber	—	0	0	—	0
D(4 Min) Value						
Flaming	NBS Smoke	—	1	1	—	0
Non-flaming	Chamber	—	0	0	—	0
Toxicity Index 10 g(0.02 lbs) sample						
CO	NES 713	—	0.074	0.065	—	0.051
CO_2	on Cable	—	0.146	0.124	—	0.123
Total for all gases tested		—	0.22	0.19	—	0.17

ELECTRICAL PROPERTIES

Dielectric strength	ASTM D149 (50µ film)	KV/cm	190	—	—	—
Comparative tracking index 23°C (73°F)	D3638	Volts	150	—	175	—
Loss tangent 23°C(73°F) 1Hz	BS 2782	—	0.003	—	—	—
Volume resistivity 23°C(73°F)	D257	ohm-cm	4.9 x 10^{16}	—	—	1.4 x 10^{5}
Permittivity						
50 Hz-10 KHz, 0-150°C(32-300°F)	BS 2782	—	3.2-3.3	—	—	—
50 Hz 200°C(390°F)	BS 2782		4.5			

■ Estimated Value

3 Summary of Chemical Resistance

'Victrex' PEEK exhibits excellent resistance to a wide range of organic and inorganic chemicals.

The compatibility of 'Victrex' PEEK with many chemicals at 20°C (68°F) has been investigated and the results for unreinforced grades are given in Table 1.

These results are derived from tests in which unstressed specimens were completely immersed in a wide range of chemical environments at room temperature. They may differ considerably from those found in service, especially in the effects of stresses and strains set up during fabrication, and of elevated temperatures. These conditions, particularly those of stress and strain, are difficult to reproduce in the laboratory. Table 1, therefore, should be used only as a guide, and the user should satisfy himself beforehand of the suitability of 'Victrex' PEEK for the in-service environment.

Some results at higher temperatures are available; these are given in Table 2.

Table 1 The Chemical Resistance of Unreinforced 'Victrex' PEEK 450G at 20°C (68°F)

Chemical	Rating	Chemical	Rating	Chemical	Rating
Acetaldehyde	A	Ethane	A	Nitric acid (10%)	A
Acetic acid	A	Ethanol	A	Nitric acid (30%)	B
Acetone	A	Ethyl acetate	A	Nitrobenzene	A
Acetonitrile	A	Ethyl alcohol	A	Nitrogen	A
Acrylic acid	A	Ethylene oxide	A	Nitrous acid (10%)	A
Aluminium sulphate	A				
Ammonia, anhydrous	A	Ferric oxide	A	Oxygen	A
Ammonia (liquid)	B	Ferric sulphate	A	Ozone	A
Ammonium hydroxide conc.	A	Fluorine	C		
Aqua – regia	C	Formic acid	B	Paraffin	A
		Formalin	A	Pentane	A
Benzene	A			Perchloroethylene	A
Benzoic acid	A	Gas (natural)	A	Phenol (dilute)	A
Benzaldehyde	A	Gas (manufactured)	A	Phenol (conc)	C
Bromine/dibromoethane	C	Gasoline (sour)	A	Phosphoric acid (10%)	A
Bromine (dry)	C	Glycols	A	Phosphoric acid (50%)	A
Bromine (wet)	C			Phosphoric acid (80%)	A
Boric acid	A	Heptane	A	Phthalic acid	A
Butane	A	Hexane	A	Potassium chloride	A
		Hydraulic oil	A	Potassium hydroxide (dilute)	A
Calcium carbonate	A	Hydrochloric acid	A	Potassium hydroxide (70%)	A
Calcium chloride	A	Hydrobromic acid	C	Potassium sulphate	A
Calcium hydroxide	A	Hydrofluoric acid	C	Propane	A
Carbolic acid	A	Hydrogen peroxide	A	Propanol	A
Carbonic acid	A	Hydrogen sulphide (gas)	A		
Carbon dioxide (dry)	A			Sodium (hot)	C
Carbon tetrachloride	A	Iodine	B	Sodium carbonate	A
Chlorinated solvents	B	Iso-octane	A	Sodium hydroxide	A
Chlorine (gas)	A			Sodium hypochlorite	A
Chlorine (liquid)	C	Kerosine	A	Styrene (liquid)	A
Chlorobenzene	A	Ketones	A	Sulphur hexafluoride (gas)	A
Chloroform	A			Sulphuric acid (up to 40%)	A
Crude oil	A	Lactic acid	A	Sulphuric acid (40%)	C
Cyclohexane	A				
Chromic acid (40%)	A	Magnesium chloride	B	Tetraethyl lead	A
Chlorine water (sat)	C	Magnesium hydroxide	A	Toluene	A
		Maleic acid	A	Trichloroethylene	A
Diethylamine	A	Methane	A	1 1 1 Trichloroethane	A
Diethyl ether	A	Methanol	A	Trichlorotrifluoroethane	A
Dimethylformamide	A	Methyl alcohol	A		
Diphenyl sulphone	B	Methyl ethyl ketone	A	Water	A
		Methylene chloride	A		
				Xylene	A
				Zinc chloride	A
				Zinc sulphate	A

A = No attack. Little or no absorption.
B = Slight attack. Satisfactory use of 'Victrex' PEEK will depend on the application.
C = Severe attack. 'Victrex' PEEK should not be used for any application where these chemicals are present.

5 Resistance to Inorganic Chemicals

'Victrex' PEEK shows excellent resistance to inorganic chemicals and exhibits good retention of mechanical properties after long term exposure.

Unreinforced grades of 'Victrex' PEEK are very resistant to attack by inorganic chemicals. At high temperatures, they are affected to some extent by strong acids and alkalis, including sulphuric acid, sodium hydroxide and ammonia.

Acids can cause embrittlement but have little effect on stiffness. Both acids and alkalis may result in some loss of tensile strength. Glass fibre reinforced grades of 'Victrex' PEEK are more resistant to acidic chemicals than are unreinforced grades. On the other hand, strong alkalis have a more pronounced effect on glass fibre reinforced grades, causing changes in weight and dimensions, as well as a reduction in mechanical properties in the most extreme cases.

The bearing grade, 'Victrex' PEEK 450FC30, is more chemically resistant than either the glass fibre reinforced or unreinforced equivalents. Physical changes and changes in mechanical properties are minimal. As with the glass fibre reinforced grades, the effect of strong alkalis is more pronounced than that of acids.

The effect of various inorganic chemicals on the physical and mechanical properties of unreinforced and reinforced grades of 'Victrex' PEEK is shown in Tables 6 - 15.

Table 6 Weight and Dimensional Changes of 'Victrex' PEEK 150G after Immersion in Inorganic Chemicals for Seven Days at 200°C (420°F)

Environment	Weight change %	Change in dimensions %		
		x	y	z
Phosphoric acid (50%)	+0.7	N/C	N/C	N/C
Sulphuric acid (50%)	+0.5	−0.3	−0.8	N/C
Sodium hydroxide solution (50%)	+11.3	−0.5	−0.5	+2.0
Liquid ammonia	+0.8	+0.1	+0.2	+0.7
Sulphur dioxide gas	−0.5	-0.2	N/C	N/C
Hydrogen sulphide gas	N/C	−0.4	−0.1	+0.1
Carbon monoxide gas	−0.1	−0.2	−0.1	+0.3
Ammonia gas	−0.1	−0.1	−0.6	N/C

N/C = No change

x = along flow direction
y = 90° to flow direction
z = through thickness direction

Table 7 Effect on Mechanical Properties of 'Victrex' PEEK 150G of Immersion in Inorganic Chemicals for Seven Days at 200°C (420°F)

Environment	Tensile strength MPa (psi)	Retention of original value %	Flexural modulus GPa (psi)	Retention of original value %	Elongation at break %	Retention of original value %
Phosphoric acid (50%)	108 (15,650)	103	3.4 (493,000)	92	5.1	107
Sulphuric acid (50%)	66 (9,570)	63	4.3 (623,500)	118	2.0	43
Sodium hydroxide soln. (50%)	63 (9,089)	65	2.5 (360,024)	64	7.3	71
Liquid ammonia	87 (12,681)	90	3.7 (537,600)	96	9.4	91
Sulphur dioxide gas	105 (15,217)	108	4.0 (582,400)	104	4.9	47
Hydrogen sulphide gas	108 (15,640)	111	4.0 (582,400)	105	6.1	78
Carbon monoxide gas	104 (15,153)	108	3.9 (571,200)	102	6.3	61
Ammonia gas	106 (15,358)	109	4.1 (588,000)	105	9.6	95

Table 8 Weight and Dimensional Changes of 'Victrex' PEEK 150GL30 after Immersion in Inorganic Chemicals for Seven Days at 200°C (420°F)

Environment	Weight change %	Change in dimensions %		
		x	y	z
Phosphoric acid (50%)	+0.6	N/C	N/C	N/C
Sulphuric acid (50%)	+0.7	N/C	N/C	N/C
Sodium hydroxide solution (50%)	−44.2	−0.6	−6.5	−32.0
Liquid ammonia	−0.6	N/C	−0.2	N/C
Sulphur dioxide gas	N/C	N/C	N/C	−0.2
Hydrogen sulphide gas	N/C	−0.3	−0.1	+0.4
Carbon monoxide gas	−0.1	N/C	N/C	−0.1
Ammonia gas	−0.1	+0.1	−0.2	N/C

N/C = No change

x = along flow direction
y = 90° to flow direction
z = through thickness direction

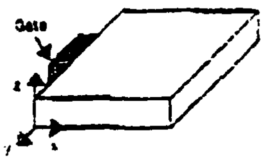


Table 9 Effect on Mechanical Properties of 'Victrex' PEEK 150GL30 after Immersion in Inorganic Chemicals for Seven Days at 200°C (420°F)

Environment	Tensile strength MPa (psi)	Retention of original value %	Flexural modulus GPa (psi)	Retention of original value %	Elongation at break %	Retention of original value %
Phosphoric acid (50%)	139 (20,155)	84	8.8 (1,276,000)	90	2.5	87
Sulphuric acid (50%)	135 (19,575)	82	8.9 (1,290,500)	91	2.6	90
Sodium hydroxide soln. (50%)	97 (14,148)	61	8.8 (1,276,000)	79	1.4	55
Liquid ammonia	142 (20,609)	74	10.8 (1,561,700)	97	1.9	73
Sulphur dioxide gas	176 (25,522)	92	11.5 (1,674,400)	104	2.1	81
Hydrogen sulphide gas	178 (25,900)	93	11.2 (1,626,000)	101	2.1	83
Carbon monoxide gas	173 (25,066)	90	12.1 (1,754,900)	109	2.0	75
Ammonia gas	178 (25,900)	93	11.5 (1,674,400)	104	2.1	82

6 Resistance to Organic Chemicals

Because of its semi-crystalline nature 'Victrex' PEEK offers excellent resistance to organic chemicals and commonly used solvents and exhibits good retention of mechanical properties after long term exposure. At high temperatures, some reagents will have an effect on weight, dimensions and mechanical properties: in particular methyl ethyl ketone and nitrobenzene can have a significant effect on weight and dimensions, and result in plasticisation of the polymer.

Glass fibre reinforced grades are less affected and the bearing grade 450FC30 even less so.

The effect of some organic chemicals on the physical and mechanical properties of 'Victrex' PEEK is shown in Tables 16 - 25.

Table 16 Weight and Dimensional Changes of 'Victrex' PEEK 150G after Immersion in Organic Chemicals for Seven Days at 200°C (420°F)

Environment	Weight change %	Change in dimensions %		
		x	y	z
Acetic acid (pure)	+2.2	−0.2	+0.3	+2.2
Ethylene glycol	+2.5	+0.2	N/C	N/C
Methyl ethyl ketone	+5.6	+0.9	+2.0	+3.2
Nitrobenzene	+15.6	+2.8	+5.4	+8.6
Methane	−0.4	−0.3	−0.1	N/C

N/C = No change

x = along flow direction
y = 90° to flow direction
z = through thickness direction

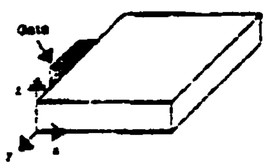


Table 17 Effect on Mechanical Properties of 'Victrex' PEEK 150G of Immersion in Organic Chemicals after Seven Days at 200°C (420°F)

Environment	Tensile strength MPa (psi)	Retention of original value %	Flexural modulus GPa (psi)	Retention of original value %	Elongation at break %	Retention of original value %
Acetic acid (pure)	108 (15,660)	102	3.5 (507,500)	95	9.9	152
Ethylene glycol	87 (12,615)	83	3.9 (565,500)	91	3.2	108
Methyl ethyl ketone	75 (10,875)	72	3.7 (536,500)	[illegible]	22.0	178
Nitrobenzene	57 ([illegible]265)	55	1.5 (217,500)	41	56.8	191
Methane	113 (16,344)	116	4.0 (582,[illegible])	[illegible]	[illegible]	65

7 Resistance to Refrigerants

'Victrex' PEEK is resistant to attack by halogenated hydrocarbon solvents and refrigerants.

Table 26 Weight Change of 'Victrex' PEEK after Immersion in Various 'Arcton' Refrigerants for Seven Days at 23°C (73°F)

Grade	Weight change %			
	'Arcton' 11	'Arcton' 12	'Arcton' 22	'Arcton' 114
450G	0.0	−0.11	N/A	0.0
450GL30	−0.1	−0.05	0.0	0.0
450CA30	0.0	+0.05	+0.09	+0.07

N/A = Not available

Table 27 Percentage Change in Mechanical Properties of 'Victrex' PEEK after Immersion in 'Arcton' A134a* for Fourteen Days at 100°C (212°F)

Grade	Change %	
	Tensile strength	Flexural modulus
450G	+9.3	+7.0
450GL30	+4.0	+0.4
450FC30	+10.0	−13.8

*'Arcton' A134a is a novel "environment friendly" refrigerant developed by ICI.

8 Resistance to Aviation and Automotive Fluids

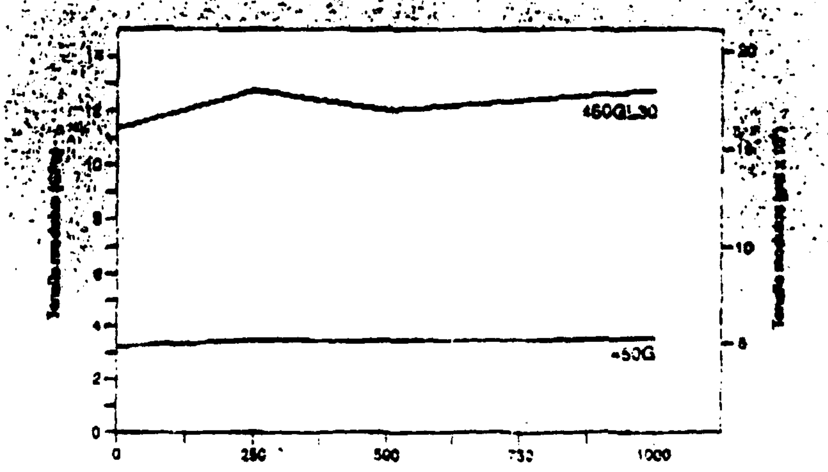
Both unreinforced and reinforced 'Victrex' PEEK show excellent resistance, even at elevated temperatures, to the majority of substances encountered in the aviation and automotive areas: they include hydrocarbon and mineral oils, greases and transmission fluids.

Resistance to Aviation Fluids

'Victrex' PEEK has excellent resistance to 'Skydrol' 500B-4 and LD4 hydraulic fluids as can be seen from Figures 2 - 5 and Tables 28 and 29.

Figure 2

Effect of 'Skydrol' 500B-4 on the Tensile Modulus of 'Victrex' PEEK at 80°C (176°F)



APPENDIX D

Information on Polychlorotrifluoroethylene (CTFE) Provided by Allied Signal

ACLAR can be heat-sealed, laminated, printed, thermoformed, metallized, and sterilized. The unsupported and laminated varieties can be handled and processed on most common converting and packaging machinery.

Very few films combine so many desirable qualities as **ACLAR**. It is:

- Unsurpassed in moisture barrier protection; up to ten times more moisture protection than other clear, flexible films
- FDA recognized. Applicable regulation #21CFR177.1380. Drug Master File No. 1578.
- Crystal clear
- Chemically stable and biochemically inert
- Plasticizer and stabilizer free
- Transparent to ultraviolet radiation
- Nonflammable
- Nonsticking
- Non-aging
- Low in dielectric constant and dissipation; high in dielectric strength

Grades

ACLAR 22A is a copolymer film consisting primarily of CTFE. It is used primarily for pharmaceutical packaging applications. ACLAR 22A film thermoforms at a lower temperature than ACLAR 33C and may be formed on a vacuum forming machine. ACLAR 22A provides excellent moisture barrier properties. Standard product thicknesses include .0015" and .005".

ACLAR 88A is a copolymer film consisting primarily of CTFE. It is used primarily for pharmaceutical packaging applications as well. This product thermoforms at the same temperature and on identical equipment as ACLAR 22A. It is available in the thickness of .00075" only.

ACLAR 22C is a copolymer film consisting primarily of CTFE. It is used primarily as an encapsulating film for electroluminescent lamps and for clean room packaging. Standard product thicknesses include .002", .003", .005", .0075", and .01".

ACLAR 33C is a terpolymer film consisting primarily of CTFE. It is used primarily for military and pharmaceutical packaging applications. It thermoforms satisfactorily on equipment having a pre-heat station and a plug assist system. ACLAR 33C provides superior moisture barrier properties. It is available in standard thicknesses of .00075", .001", .002", .003", .005", and .0075".

ACLAR Laminations—Laminated structures containing various grades of ACLAR film are available for a variety of end-use applications. Please ask your ACLAR specialist for more details.

Typical Properties

ACLAR® CTFE film is a clear, flexible thermoplastic film with excellent dimensional stability. It is unsurpassed as a transparent packaging material for moisture sensitive products. Key physical and thermal properties of **ACLAR®** film products are summarized below.

		ACLAR 88A	ACLAR 22A	ACLAR 22C	ACLAR 33C	Test Method
Gauge, Mils (Microns)		.75 (19)	1.5 (38)	7.5 (190)	.75 (19)	
Yield, Sq. In./Lb. (m^2/Kg)		17,760 (25.25)	8880 (12.62)	1750 (2.49)	17,360 (24.68)	
Specific Gravity		2.10	2.10	2.11	2.12	ASTM D-1505
Haze, %		<1	<1	<1	<1	ASTM D-1003
Tensile Strength	MD, Psi (KPa)	7.0–10.0 x 10^3 (48.3–69 x 10^3)	7.5–11.0 x 10^3 (51.7–75.9 x 10^3)	4.0–6.0 x 10^3 (27.6–41.4 x 10^3)	9.5–11.5 x 10^3 (65.5–79.3 x 10^3)	ASTM D-882
	TD, Psi (KPa)	4.0–6.0 x 10^3 (27.6–41.4 x 10^3)	5.5–8.0 x 10^3 (37.9–55.2 x 10^3)	4.0–6.0 x 10^3 (27.6–41.4 x 10^3)	5.5–8.0 x 10^3 (37.9–55.2 x 10^3)	
Elongation, %	MD TD	150–250 200–300	115–225 200–300	200–300 200–300	50–150 50–150	ASTM D-882
Young's Mod.	MD, Psi (KPa)	140–160 x 10^3 (97–110 x 10^4)	140–160 x 10^3 (97–110 x 10^4)	130–160 x 10^3 (90–110 x 10^4)	190–200 x 10^3 131–138 x 10^4	ASTM D-882
	TD, Psi (KPa)	120–140 x 10^3 (83.7–97 x 10^4)	150–160 x 10^3 (104–110 x 10^4)	130–160 x 10^3 (90–110 x 10^4)	190–200 x 10^3 (131–138 x 10^4)	
Tear Strength-Init. (Graves), gm	MD TD	240 300	380 360	465 415	400 380	ASTM D-1004
Tear Strength, Propagated (Elmendorf), gm	MD TD	24 24	40 130	>1600 >1600	12 33	ASTMD-1922
Impact Strength (Dart drop) Failure Weight, gms		93 (Method "A")	347 (Method "A")	1200 (Method "B")	<57 (Method "A")	ASTM-1709 "A"—26", 1.5" diam. dart (66 cm, 3.8 cm diam. dart) "B"—60", 2" diam. dart (152 cm, 5.1 cm diam. dart)
Dimensional Change, %	MD TD	+12 to +15 −12 to −15	+12 to +15 −12 to −15	≤2 ≤2	≤2.5 ≤2.5	ASTM D-1204 300°F (149°C) 10 min
Crystalline Melting Point	TM °F (°C)	361–367 (183–186)	361–367 (183–186)	361–367 (183–186)	396–400 (202–204)	
Abrasion Resistance Weight loss, mgs.		14(A)	16(A)	7(A)	15(B)	Taber abraser "A"—CS 10 wheel 500 gm – 100 cycles "B"—CS 10F wheel 500 gm – 500 cycles
Therm. Conduct.	Cal-Cm / Cm^2-Sec-C°	5.3 x 10^{-4}	5.3 x 10^{-4}	5.3 x 10^{-4}	4.7 x 10^{-4}	
Flammability		Non Flam	Non Flam	Non Flam	Non Flam	ASTM D-568
Oxygen Index, %		100	100	100	100	ASTMD-2863

Permeability

ACLAR has an outstanding ability to prevent the passage of water vapor and liquids. This means that **ACLAR** gives superb product protection and, because of its transparency, permits inspection viewing of the product at the same time. These combined properties have inspired imaginative new product designs for moisture-sensitive items.

Water Vapor Transmission Rate*
Unsupported ACLAR Film

		Gm/100 In.^{2}/24 Hrs.		Gm/m^2/24 Hrs.
ACLAR 33C	0.75 mil	.033 (±.005)	19 μ	0.51 (±.08)
	2.0 mil	.015 (±.005)	51 μ	0.23 (±.08)
ACLAR 22C	1.0 mil	.045 (±.015)	25.4 μ	0.70 (±.23)
	2.0 mil	.028 (±.012)	51.0 μ	0.43 (±.19)
	7.5 mil	.007 (±.001)	190.0 μ	0.11 (±.02)
ACLAR 22A	1.5 mil	.030 (±.01)	38 μ	0.47 (±.15)
ACLAR 88A	0.75 mil	.050 (±.005)	19 μ	0.78 (±.08)

*Measured on sealed pouches @ 100°F @ 90% RH.
ASTM E-96 Method E

Water Vapor Transmission of Typical ACLAR Laminations**

	Gm/100 In.^{2}/24 hrs.	Gm/m^2/24 hrs.
1.5 mil **ACLAR 22A**/2 PE/7$^1/_2$ PVC	0.022	0.34
0.75 mil **ACLAR 88A**/2 PE/7$^1/_2$ PVC	0.031	0.48
0.75 mil **ACLAR 33C**/10 PVC	0.018	0.28

**Measured on a MOCON PERMATRAN @ 100°F @ 90% RH.
ASTM-F372-78

		Water Vapor Transmission gm–mil/100 in²/24 hrs. @ 100°F @ 90% RH (gm–mm/m²/24 hrs @ 37.8°C @ 90% RH)	Gas Transmission cc (STP) mil/100 in²/24 hr–ATM @ 77°F (cc (STP)–mm/m²/24 hr–ATM @ 25° C)		
			O_2	N_2	CO_2
ACLAR 33C		See table at left	7 (2.8)	— —	16 (6.3)
ACLAR 22C		See table at left	15 (5.9)	2.5 (1.0)	40 (15.7)
ACLAR 22A		See table at left	12 (4.7)	2.5 (1.0)	30 (12.0)
PVC/PVdC copolymer		0.20–0.6 (0.08–0.24)	0.8–6.9 (0.3–2.7)	0.12–1.5 (0.05–0.6)	38–44 (15–17)
Polyethylene	Low density	1.0–1.5 (0.39–0.59)	500 (195)	180 (71)	2700 (1060)
	Medium density	0.7 (0.28)	250–535 (100–210)	85–315 (35–125)	100–2500 (40–985)
	High density	0.3 (0.12)	185 (73)	42 (17)	580 (230)
CAPRAN® 77C (Nylon 6)		19–20 (7.5–7.9)	2.6 (1.0)	0.9 (0.35)	4.7 (1.9)
Fluorinated ethylene propylene		0.4 (0.16)	750 (295)	320 (125)	1670 (660)
Polyvinyl fluoride		3.24 (1.3)	3.0 (1.2)	0.25 (.10)	11 (4.3)
Polyvinylidene fluoride		2.6* (1.0)	1.4 (.55)	9 (3.5)	5.5 (2.2)
Polyester—PET oriented		1.0–1.3 (.39–.51)	3.0–6.0 (1.2–2.4)	0.7–1.0 (0.28–0.39)	15–25 (5.9–9.8)

*23°C

CAPRAN® is a registered trademark of Allied-Signal Corp.

Chemical Resistance

ACLAR resists attack by most industrial chemicals—acids, alkalis, and many solvents. Exceptions include alkali metal complexes and organic amines. A certain few materials such as highly chlorinated-fluorinated solvents, nitrogen tetroxide, and chlorine gas tend to plasticize the film. Silicones tend to induce stress cracking.

The following table reports the effect of many chemicals on **ACLAR**. Specimens were exposed for two weeks at ambient temperatures.

Chemical Resistance Table

Material	Average Weight Increase (%)		Visible Effect on Sample	
	ACLAR 22 & 88	**ACLAR 33**	**ACLAR 22 & 88**	**ACLAR 33**
Acetic Acid (3%)	None	None	None	None
Acetic Acid (Glacial)	0.09	0.03	None	None
Acetone	5.17	0.5	Clouded, extremely flexible	None
Acetophenone	None	None	None	None
Ammonium Hydroxide	None	None	None	None
Aniline	0.01	None	None	None
Aqua Regia	0.10	0.04	Clear, yellow discoloration	None
Benzaldehyde	0.02	None	None	None
Benzene	2.4	0.6	Clouded, flexible	None
Benzoyl Chloride	0.14	None	None	None
Bromine	0.15	0.1	Clear, amber discoloration	Clear, amber discoloration
Butyl Alcohol	—	None	—	None
Carbon Disulfide (ACS)	0.4	0.2	Clouded	None
Carbon Tetrachloride	4.1	1.6	Flexible	Slightly flexible
Citric Acid (3%)	None	None	None	None
Cyclohexanone	0.35	None	Clouded	None
1, 2-Dichloroethane	0.11	0.03	Clouded	None
2, 4-Dichlorotoluene	0.15	0.06	Clouded	None
Diethyl Phthalate	None	None	Clouded	None
Dimethylhydrazine (anhy.)	3.9	1.8	Blistered	Amber discoloration
Dioxan	1.9	0.15	Flexible	None
Ethyl Acetate	7.65	6.0	Extremely flexible	Very flexible
Ethyl Alcohol (Anhyd. Denat.)	None	None	None	None
Ethyl Ether	5.6	5.2	Clouded, extremely flexible	Very flexible
Ethylene Oxide	5.8	4.0	Clouded, extremely flexible	Very flexible
Formic Acid	None	None	None	None
Furan, B.P. 31°–32°C.	5.4	3.7	Smokey discoloration, extremely flexible	Very flexible
Gasoline (Premium Grade)	0.83	0.2	Clear, amber discoloration	None
Heptane	None	None	Slightly clouded	None
Hexachloroacetone—20% Deeprock Heavy Cycle Oil (35-40% Aromatic)	None	None	None	None

Chemical Resistance Table

Material	Average Weight Increase (%) ACLAR 22 & 88	ACLAR 33	Visible Effect on Sample ACLAR 22 & 88	ACLAR 33
Hexachloroacetone—20% Kerosene	None	None	None	None
Hydraulic Fluid (Monsanto Fluid OS-45)	None	None	None	None
Hydraulic Fluid (Monsanto Pydraul F9)	None	None	None	None
Hydrochloric Acid (10%)	None	None	None	None
Hydrochloric Acid (Conc. 36%)	None	None	None	None
Hydrofluoric Acid (60%)	None	None	None	None
Hydrogen Peroxide (30%)	0.23	None	Clouded	None
JP-4 Referee Grade	0.09	0.03	None	None
JP-4 Flight Grade	0.02	0.01	None	None
Lactic Acid (3%)	None	None	None	None
Liquid Oxygen	—	—	Passes lox *impact test*	Passes lox *impact test*
Malathion EM-J	0.05	None	None	None
Methanol	0.10	None	None	None
Methyl Ethyl Ketone	5.9	1.2	Extremely flexible	Slightly flexible
Nitric Acid (10%)	None	None	None	None
Nitric Acid (Conc. 70%)	None	None	None	None
Nitric Acid (Red Fuming)	0.07	0.04	None	None
Nitric Acid (Conc.)—Hydrofluoric Acid (60%) (50:50)	None	None	None	None
Nitrogen Tetroxide	—	—	Flexible, yellow discoloration	Flexible, yellow discoloration
Oil (Motor Premium Grade)	0.01	0.01	None	None
2, 4-Pentanedione	0.17	0.20	Clouded	None
Pyridine	0.55	0.1	Clouded	None
Sodium Hydroxide (50%)	None	None	None	None
Sodium Hypochlorite	None	None	None	None
Sulfuric Acid (30%)	None	None	None	None
Sulfuric Acid (Fuming 20%)	0.03	0.02	None	None
Toluene	2.8	1.1	Flexible	Slightly flexible
Toluene Diisocyanate	0.44	—	None	—
1, 1, 2-Trichloroethane (Tech.)	0.04	0.02	Clouded	None
Trichloroethylene	10.9	7.8	Clouded, extremely flexible	Clear, very flexible
Trichlorotrifluoroethane (Genesolv D)	—	—	Cloudy, extremely flexible	Cloudy, very flexible
Triethylaluminum	0.13	0.01	Slightly crazed	Slightly crazed

APPENDIX E

Information on Polyvinylidene fluoride (PVF_2, KYNAR)
Provided by
Soltex Polymer

Wide range of products

HOMOPOLYMERS

TYPE	APPEARANCE	CHARACTERISTICS AND MAIN USAGES
Series 1000		**Virgin resins**
SOLEF 1006	translucent	Applications requiring high fluidity: Multifilaments, injection moulding of parts with very thin walls.
SOLEF 1008	translucent	Injection moulding - general: Injection moulding of complicated shapes or thin walls. Extrusion of thin walls, particularly of tubes < 8 mm diameter. Transfer and centrifugal moulding. Film extrusion.
SOLEF 1010	translucent	Standard grade. General extrusion and injection moulding. Extrusion of tubes, films, sheets and thin panels (5 μm - 12 mm). Compression and transfer moulding. Blow moulding of films (5 to 100 μm) and hollow objects.
SOLEF 1012	translucent	Applications where low fluidity is required: Extrusion of thick walls, particularly for large diameter tubes and heavy sections. Compression moulding.
Series 6000		**Improved thermal stability virgin resins**
SOLEF 6010	translucent	Thick semi-finished items.
Series 4000		**Pigmented master batches,** to be diluted ten times (25 colours available).
Series 3000		**Compounds for special applications**
SOLEF 3108	black	Anti-static: formula reinforced with carbon black. Extrusion or injection moulding of anti-static units.
SOLEF 3208	translucent	Self-lubricating: formula lubricated with PTFE. Applications requiring low friction coefficient (e.g. valve seatings).
Series 8000		**Reinforced grades to obtain a high dimensional stability**
SOLEF 8808	black	Grade reinforced with carbon fibres. Applications requiring extremely high rigidity.
SOLEF 8908	brown	Grade reinforced with mica. Applications requiring very high rigidity and low warpage.
Series 5000		**Special size graded powders**
SOLEF 5008	translucent	Top coat for electrostatic powder spraying.
SOLEF 5508	red	Primer for electrostatic powder spraying.
SOLEF 5708	translucent	Rotational moulding grade.

COPOLYMERS

TYPE	APPEARANCE	CHARACTERISTICS AND MAIN USAGES
SOLEF 11010	translucent	Virgin resin. For use where more flexibility and very high elongation at break are required: electric and telephone cable sheathing, extrusion of sheets.
SOLEF 11010/0003	translucent	Electric and telephone cables requiring good resistance to flame spreading and low smoke emission (approved by the UNDERWRITERS' LABORATORIES for UL 910 and UL 94 V-O tests).

Other grades are available on request for specific uses.

Very high performance

Table 1 - Main characteristics of SOLEF PVDF

PROPERTIES	STANDARDS	UNITS	1008 INJECTION	1010 EXTRUSION	1012 SEMI-FINISHED	3108 ANTI-STATIC	3208 ANTI-FRICTION	8808 REINFORCED CF*	8908 REINFORCED MICA	11010 COPOLYMER EXTRUSION
PHYSICAL PROPERTIES										
Density	ASTM D 792	g/cm^3	1.78			1.73	1.78	1.78	1.84	1.77
Water absorption (24 h at 23°C)	ASTM D 570	%	< 0.04			0.07	0.04	0.05	0.04	< 0.04
Refractive index at 23°C	ASTM D 542	-	1.42			-	-	-	-	1.41
Melt flow index	ASTM D 1238									
- 230°C, 10 kg		g/10 min	50	13	4	17	55	52	38	22
- 230°C, 5 kg		g/10 min	18	4	1	6	20	19	16	5
- 230°C, 2.16 kg		g/10 min	6	1	0.2	1	6	5	-	-
MECHANICAL PROPERTIES										
Tensile:										
Tensile stress at yield, 5 mm/min	ASTM D 638	MPa	57	54	51	50	53	93	49	31
Ultimate tensile strength, 5 mm/min	ASTM D 638	MPa	50	46	43	43	46	93	47	25
Elongation at break, 5 mm/min	ASTM D 638	%	12	80	100	9	70	1	6	430
Modulus at 1 mm/min	ASTM D 638	MPa	2600	2400	2100	3800	2300	6000	4200	1000
Flexion:										
Maximum load	ASTM D 790	MPa	94	74	70	89	78	170(1)	81	49
Modulus	ASTM D 790	MPa	2500	2300	2000	4500	2200	6000 (1) rupture	4700	1000
Compression:										
Max. strength at 1 mm/min	ASTM D 695	MPa	85	80	75	90	80	96	-	49
Modulus at 1 mm/min	ASTM D 695	MPa	2900	2400	2100	3800	2300	6000	-	-
Shore D Hardness	-	-	79	77	77	82	78	82	81	72
Tensile impact strength	DIN 53448									
- on pressed sheets		kJ/m^2	300	400	400	150	300	270	-	570
- on injected sheets		kJ/m^2	600	600	600	-	-	-	147	700
Abrasion resistance	TABER CS 10 (load 1 kg)	mg. (1000 cycle)$^{-1}$	5 - 10						18	10
Friction coefficient	ASTM D 1894									
- static			0.45	0.45	0.45	0.33	0.20	0.33	0.28	0.33
- dynamic			0.34	0.34	0.34	0.23	0.15	0.23	0.25	0.31
THERMAL PROPERTIES										
Vicat point (5 kg)	ASTM D 1525	°C	147	142	140	151	147	167	157	96
Deflection temperature under load	ASTM D 648 (1.8 MPa)	°C	115	113	105	129	117	134	-	54
Glass transition point	ASTM D 2236	°C	-40			-35	-40	-35	-	-35
Crystalline melting point		°C	177			177	174	176	177	162
Linear thermal expansion coefficient	ASTM D 696	K^{-1}	106×10^{-6}	128×10^{-6}	143×10^{-6}	36×10^{-6}	106×10^{-6}	36×10^{-6}	-	120×10^{-6}
Thermal conductance (20 - 150°C)	ASTM C 177	W.m^{-1}.K^{-1}	0.19			0.23	0.19	0.22	-	0.17
Specific heat (between 0 and 100°C)		J.kg^{-1}.K^{-1}	960			-	-	-	-	960
Crystalline fusion heat	calorimetry	kJ.kg^{-1}	71	66	63	54	60	57	-	38
ELECTRICAL PROPERTIES										
Volume resistivity	ASTM D 257	Ω . cm	5×10^{14}			$<10^{4}$**	1×10^{14}	2×10^{13}	1.8×10^{14}	6×10^{14}
Surface resistivity	DIN 53483	Ω	$>10^{13}$			$<10^{3}$	$>10^{13}$	2×10^{12}	1.5×10^{14}	5×10^{14}
Moulding shrinkage		%	2 - 3			2	2 - 3	1	1	2

*CF = Carbon fibres

SOLEF® PVDF

TABLES OF CHEMICAL RESISTANCE

SOLEF PVDF is remarkably resistant to most inorganic acids and bases, aliphatic and aromatic hydrocarbons, organic acids, alcohols, and halogenated solvents. It is also resistant to the halogens (chlorine, bromine, and iodine, but not to fluorine).

It is degraded by fuming sulphuric acid (oleum), some strongly basic amines, concentrated alkalis, and alkali metals. It swells slightly in strongly polar solvents such as acetone and ethyl acetate, and is soluble with difficulty in aprotic polar solvents such as dimethylformamide, dimethylsulphoxide, tetramethylurea or hexamethylphosphotriamide.

The following tables give an indication of the chemical resistance of SOLEF PVDF grades 1008, 1010, 1012, and 5008. The chemical substances are listed according to the rules of the "Handbook of Chemistry and Physics" published by The Chemical Rubber Company, 59th edition. The solutions are aqueous, unless otherwise indicated. The "%" sign indicates "g of solute per 100g solution". The term "sat." indicates a concentration such that the solution is saturated at 25°C.

The tables are divided into two parts. The left-hand side gives the chemical resistance of solid SOLEF PVDF, as it is used for tubes, fittings, linings, pumps, etc. The right-hand side refers solely to powder coatings applied by electrostatic spraying or by fluidized bed.

In order to determine the chemical resistance of solid SOLEF PVDF, stress free test pieces (2 mm thick) were completely immersed for 30 days in each medium. After drying the surface, they were measured, weighed and subjected to a tensile test.

The assessments about solid SOLEF PVDF do not take into account possible diffusion of a substance through the material. In addition, resistance of pipe made of SOLEF PVDF to pressure has been evaluated as a function of time and temperature, in the presence of numerous chemicals. An asterisk (*) shows which compounds listed in the tables have been tested in this way.

For powder coatings (right hand column), carbon steel plates coated by electrostatic spraying (average thickness of the coating 400 microns —.016") were immersed in each medium for 30 days. After drying, the plates were weighed and their appearance examined. The porosity of the coating was then tested using an electric spark technique. The adherence of the coating was checked using a test developed by the SOLVAY Laboratory. The assessments about powder coatings take into account possible diffusion of a substance through the PVDF..

SIGNS USED AND EVALUATION CRITERIA

SOLID SOLEF PVDF (thickness ≥ 1 mm)

+ : SOLEF PVDF is resistant -
  1) Its dimensions change by not more that 1.25%
  2) Its weight changes by not more than 2%
  3) Its tensile yield strength does not change by more than 15%

o : Use of SOLEF PVDF is limited -
  The response to at least one of the three criteria above was negative. For instance the weight changes between 2% and 5%. However, SOLEF PVDF can be used in the medium, provided that it is not subjected to undue stress (e.g. for linings, reinforced parts, etc). In this case, it is recommended to obtain advice from SOLTEX.

— : SOLEF PVDF is not resistant -
  There is considerable deterioration of the material: dissolution, chemical or physical attack, permeability, etc. For instance the weight changes by more than 5%.

B.P.: Boiling point of the medium concerned

SOLEF PVDF POWDER COATINGS (thickness <1 mm)

+ : The SOLEF PVDF coating is resistant -
  No visible change in either the color or permeability of the coating after at least 30 days continuous treatment in the medium concerned. The weight variation of the coating is less than 2%.

o : Use of SOLEF PVDF coating is limited -
  Coating usable with certain restrictions due, for example, to a change in color without loss of properties, or to slight swelling in a solvent. The increase in weight lies between 2% and 5%.

— : The SOLEF PVDF coating is not resistant -
  Coating unusable due to various causes which arise either individually or simultaneously, for example:
  - Chemical attack
  - Detachment of the coating
  - Change in color of the base coat
  - Permeability
  - Dissolution of the coating
  - Increase in weight of more than 5%.

POINTS TO BE NOTED

In the case of SOLEF PVDF used for coating metal surfaces, either as lining or by powder application, there is a risk of water diffusing through the coating, which increases with increasing temperature and decreasing thickness of the coating. This phenomenon is encountered only in the case of dilute solutions at temperatures above 70°C. For these applications, it is advisable to contact SOLTEX for further information.

In the case of finished articles made of Solid SOLEF PVDF, external or internal stress may make the material less resistant to certain media as the result of a phenomenon which is referred to as "stress cracking", which is well known with other polymers.

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Inorganic Media

Medium	Formula	Conc.	Solid SOLEF PVDF – Temperature Of Medium - °F / °C: 77 / 25	122 / 50	212 / 100	257 / 125	302 / 150	B.P.	SOLEF PVDF Used As Coating – Temperature Of Medium - °F / °C: 77 / 25	122 / 50	167 / 75	212 / 100	257 / 125	B.P.	B.P. °F	B.P. °C	Remarks
Aluminum																	
ammonium sulphate	$AlNH_4(SO_4)_2 \cdot 12H_2O$	50%	+	+	+			+	+	+	+	+			229	109.5	
chloride	$AlCl_3 \cdot 6H_2O$	sat.	+	+	+			+	+	+	+	+			239	115	
fluoride	AlF_3	50%	+	+	+	+											
hydroxide	$Al(OH)_3$	sat.	+	+	+	+		+	+	+	+				212	100	
nitrate	$Al(NO_3)_3 \cdot 9H_2O$	50%	+	+	+			+	+	+	+	+			224.5	107	
potassium sulfate	$Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$	50%	+	+	+			+	+	+	+	+			214	101	
Ammonia	NH_3		+	+	+	+			+	+	+	+	+				
Ammonium																	
aluminum sulfate	$AlNH_4(SO_4)_2 \cdot 12H_2O$	50%	+	+	+			+	+	+	+	+			229	109.5	
carbonate	$(NH_4)_2CO_3$	50%	+	+	+	+											
chloride	NH_4Cl	sat.	+	+	+			+	+						239	115	
hydrofluoride	$NH_4F \cdot HF$	50%	+						+								
hydroxide	NH_4OH	30%	+	+	+				+	+	+						Becomes black
nitrate	NH_4NO_3	50%	+	+	+	+		+	+	+	+	+			233.5	112	
orthophosphate	$(NH_4)_3PO_4 \cdot 3H_2O$	50%	+		+	+	+		+	+							Becomes brown
sulfate	$(NH_4)_2SO_4$	50%	+	+	+	+		+	+	+	+	+			228	109	
sulfide	$(NH_4)_2S$	20%	+	+					+								Becomes black
antimony (III) chloride	$SbCl_3$	50%	+														
		100%			—	—						—					
Barium																	
chloride	$BaCl_2 \cdot 2H_2O$	sat.	+	+	+	+		+	+	+	+				219	104	
hydroxide	$Ba(OH)_2 \cdot 8H_2O$	sat.	+	+	+	+		+	+	+	+				215.5	102	
Boric																	
acid, ortho-	H_3BO_3	sat.	+	+	+	+		+	+	+	+				215.5	102	
Boron trifluoride	BF_3		+														
Bromine	Br_2	100%	+	+	+	+			+	o	—						Slight color
		2%	+	+					+	+	o	—					
bromine water			+	+	+						—	—					
Calcium																	
carbonate	$CaCO_3$	sat.	+	+	+	+		+	+	+	+				214.5	101.5	
chloride	$CaCl_2$	sat.	+	+	+	+		+	+	+	+	+	+	+	256	124.5	
hydroxide	$Ca(OH)_2$	sat.	+	+	+	+		+	+						213	100.5	
nitrate	$Ca(NO_3)_2 \cdot 4H_2O$	50%	+	+	+	+		+	+	+	+	+			239	115	
sulfate	$CaSO_4 \cdot 2H_2O$	sat.	+	+	+	+		+	+	+	+				213	100.5	
Carbon																	
dioxide	CO_2		+	+	+	+											
sulfide-di	CS_2	100%	+						+					+	115.3	46.3	
tetrachloride	CCl_4	100%	+	+				+	+	+	+			+	170.1	76.7	
Chlorine	Cl_2	dry	+	+	+				+	+	+						
		moist	+	+	+				o	—							
chlorine water										—							
dioxide	ClO_2		+	+	+	+											
Chloric																	
acid, per-	$HClO_4$	10%	+	+	+			+	+	+	+	+			215.5	102	
		70%	+	+	+				+	+	o	—					
Chlorosulfonic acid	HSO_3Cl		o	—				—									
Chromium																	
oxide, tri-	CrO_3	30%	+	+	o	o			+	+	+	o					Becomes brown
		40%	+	+	o	o			+	+	+	o	—				Becomes brown
Copper																	
(II) chloride	$CuCl_2 \cdot 2H_2O$	50%	+	+	+			+	+	+	+				236	112.8	
(II) nitrate	$Cu(NO_3)_2 \cdot 3H_2O$	50%	+	+	+			+	+	+	+				232	111	
(II) sulfate	$CuSO_4 \cdot 5H_2O$	sat.	+	+	+			+	+	+	+				223.5	106.5	
Fluorine	F_2								—								
Fluorosilicic acid	H_2SiF_6	50%	+	+	+												

Inorganic Media

Medium	Formula	Conc.	Solid SOLEF PVDF – Temperature Of Medium – °F / °C: 77 / 25	122 / 50	212 / 100	257 / 125	302 / 150	B.P.	SOLEF PVDF Used As Coating – Temperature Of Medium – °F / °C: 77 / 25	122 / 50	167 / 75	212 / 100	257 / 125	B.P.	B.P. °F	B.P. °C	Remarks
Hydrogen																	
bromide	HBr	10%	+	+	+			+	+	+	+	+					
		25%	+	+	+			+	+	+	+	+					
		40%	+	+	+			+	+	+	+	+					
		50%	+	+	+			+	+	o					255.7	124.3	Becomes brown
		63%	—						—								
chloride	HCl	5%	+	+	+	+		+	+	+	+	—					
		10%	+	+	+	+		+	+	+	+	—					
		20%	+	+	+	+		+	+	+	—	—					
		28%	+	+	+	+		+	—	—	—						
		36%	+	+	+	+		+	—								
		42%	+	+	+	+		+	—						227.5	108.6	
		100%	+	+	+	+			+	+	+	o					
fluoride	HF	8%	+	+	+				+	+	+	+					
		36%	+	+	+				+	o	—						
		50%	+	+	+				+	o							
		70%	+	+	+				o								
iodide	HI	57%	+	+	+	+			+								Becomes brown
peroxide	H_2O_2	30%	+	+	+				+	+							
Iodine	I_2	dry	+	+													Becomes brown
		moist	+	+													Becomes brown
Iron																	
(II) chloride	$FeCl_2 \cdot 4H_2O$	sat.	+	+	+			+	+	+	+	+			247	119.5	
(III) chloride	$FeCl_3 \cdot 6H_2O$	50%	+	+	+			+	+	+	+	+			243.5	117.5	
(III) nitrate	$Fe(NO_3)_3 \cdot 9H_2O$	sat.	+	+	+			+	+	+	+	+			239	115	
(III) sulfate	$Fe_2(SO_4)3$	50%	+	+	+			+	+	+	+	+			220	104.5	
		sat.	+	+	+			+	+	+	+	+			222	105.5	
Lead																	
acetate	$(CH_3COO)_2Pb \cdot 3H_2O$	sat.	+	+	+	+		+	+						215.5	102	
Magnesium																	
carbonate, basic	$MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$	sat.	+	+	+	+		+	+	+	+	+					
chloride	$MgCl_2 \cdot 6H_2O$	50%	+	+	+				+	+	+	+			230	110	
hydroxide	$Mg(OH)_2$	sat.	+	+	+			+	+	+	+				214	101	
nitrate	$Mg(NO_3)_2 \cdot 6H_2O$	sat.	+	+	+			+	+	+	+	+			246	119	
sulfate	$MgSO_4 \cdot 7H_2O$	50%	+	+	+	+		+	+	+	+	+			216.5	102.5	
Mercury																	
(II) chloride	$HgCl_2$	sat.	+	+	+			+	+	+	+	+			215.5	102	
(II) nitrate	$Hg(NO_3)_2 \cdot H_2O$	sat.	+	+	+			+	+	+	+	+			216.5	102.5	
Nickel																	
chloride	$NiCl_2 \cdot 6H_2O$	sat.	+	+	+	+		+	+	+	+	+			248	120	
nitrate	$Ni(NO_3)_2 \cdot 6H_2O$	50%	+	+	+	+		+	+	+	+	+			247	119.5	
sulfate	$NiSO_4 \cdot 6H_2O$	sat.	+	+	+	+		+	+	+	+	+			236.5	113.5	
Nitric acid	HNO_3	6%	+	+	+	+			+	+	+	+					
		20%	+	+	+	+			+	+	o	o					
		30%	+	+	+	+			+	o							
		40%	+	+	+	+			+	o							
		50%	+	+	+	+			—								
		65%	+	+	+	+											
Oxygen	O_2		+	+	o	o											
Phosphoric																	
ortho-acid	H_3PO_4	30%	+	+	+			+	+	+	+	+			215.2	101.8	
		50%	+	+	+				+	+	+	+					
		85%	+	+	+	+		+	+	+	+	+			316.5	158	
Phosphorus																	
chloride, tri-	PCl_3								+	—							
oxychloride	$POCl_3$		+	+	o				—								
Potassium																	
aluminium sulfate	$Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$	50%	+	+	+			+	+	+	+	+			223.5	106.5	
bromide	KBr	50%	+	+	+	+		+	+	+	+	+			235.5	113	
carbonate	K_2CO_3	50%	+	+	+	+		+	+	+	+	+			244.5	118	Becomes brown
chlorate	$KClO_3$	sat.	+	+	+	+		+	+	+	+				218.5	103.5	
chloride	KCl	sat.	+	+	+	+		+	+	+	+	+			231.8	111	
dichromate	$K_2Cr_2O_7$	sat.	+	+	+	+		+	+	+	+	+		+	224.5	107	
ferrocyanide	$K_4Fe(CN)_6 \cdot 3H_2O$	50%	+	+	+			+	+	+	+	+			223.5	106.5	Becomes brown

Inorganic Media

Medium	Formula	Conc.	Solid SOLEF PVDF 77 / 25	Solid SOLEF PVDF 122 / 50	Solid SOLEF PVDF 212 / 100	Solid SOLEF PVDF 257 / 125	Solid SOLEF PVDF 302 / 150	Solid SOLEF PVDF B.P.	SOLEF PVDF Used As Coating 77 / 25	SOLEF PVDF Used As Coating 122 / 50	SOLEF PVDF Used As Coating 167 / 75	SOLEF PVDF Used As Coating 212 / 100	SOLEF PVDF Used As Coating 257 / 125	SOLEF PVDF Used As Coating B.P.	B.P. °F	B.P. °C	Remarks
			Temperature Of Medium - °F / °C														
Potassium (cont.)																	
hydroxide	KOH	50%	+	+	o	—		—	+	+	o	—			268	131	Destroyed
nitrate	KNO_3	50%	+	+	+			+	+	+	+	+			225.5	107.5	
permanganate	$KMnO_4$	sat.	+	+	+			+	+	+	+	—		—	214.5	101.5	Discoloration
sulfate	K_2SO_4	sat.	+	+	+	+		+	+	+	+	+			214.5	101.5	
sulfide	K_2S	50%	+	+	+	+											
Silver																	
nitrate	$AgNO_3$	50%	+	+	+	+		+	+	+	+	+			223.5	106.5	
cyanide	AgCN	35%	+	+	+	+											
Sodium																	
acetate	CH_3COONa	sat.	+	+	+			+	+						231.8	111	
benzoate	C_6H_5COONa	50%	+	+	+			+	+						222.8	106	
tetraborate	$Na_2B_4O_7 \cdot 10H_2O$	50%	+	+	+	+		+	+	+	+	+			217.5	103	
bromide	NaBr	50%	+	+	+			+	+	+	+	+			244.5	118	
carbonate	$Na_2CO_3 \cdot 10H_2O$	sat.	+	+	+	+		+	+	+	+	+			217.5	103	
hydrogen carbonate	$NaHCO_3$	sat.	+	+	+	+		+	+	+	+	+			215.5	102	
chloride	NaCl	sat.	+	+	+	+		+	+	+	+	+	+		214.5	101.4	
chlorate	$NaClO_3$	50%	+	+	+			+	+	+	+	+			230	110	
cyanide	NaCN	50%	+	+	+	+											
fluoride	NaF	sat.	+	+	—			—	+	+	+	+			213	100.5	
hydroxide	NaOH	0.15%	o	o	o	o		o									
		0.5%	o	o	o	o		o									
		1.5%	o	o	o	o		o									
		5%	o	o	o	o		o									
		15%	o	o	o	o		o									
		30%	o	o	o	o		o	o	o	o	o			241	116	
		40%	o	o	o	o		o	o	o	o	o	—	—	260	127	
		50%	o	o	o	o			o	o	o	o	—		287	142	
		60%	o	o	o	o				o	—				318	159	
		70%			o	—					—				356	180	
		80%				—											
hypochlorite	NaClO	5%							+								
		28%	+						+								
nitrate	$NaNO_3$	50%	+	+	+			+	+	+	+	+			233.5	112	
nitrite	$NaNO_2$	50%	+	+	+			+	+	+	+	+			238	114.5	
orthophosphate	$Na_3PO_4 \cdot 12H_2O$	50%	+	+	+	+		+	+	+	+	+			218.5	103.5	
silicate	Na_2SiO_3		+	+	+	+		+	+	+	+	+			237	114	
sulfate	Na_2SO_4	sat.	+	+	+			+	+	+	+	+			220	104.5	
hydrogen sulfate	$NaHSO_4$	50%	+	+	+	+		+	+	+	+	+			229	109.5	
sulfite	Na_2SO_3	sat.	+	+	+	+		+	+	+	+	+			217.5	103	
hydrogen sulfite	$NaHSO_3$	50%	+	+	+	+		+	+	+	+	+					
thiosulfate	$Na_2S_2O_3 \cdot 5H_2O$	50%	+	+	+	+		+	+	+	+	+			232.5	111.5	
sulfide	Na_2S	5%	o	o	o	o											
		10%	o	o	o	o											
Sulfer	S_8		+	+	+	+											
dioxide	SO_2		+	+	+	+			+	+	+	+	+				
trioxide	SO_3		o	—													
Sulfochromic																	
acid		40%	+	+	o				+	+	+	o					Becomes brown
		90%	+	+	+				+	+	+						
Sulfuric																	
acid	H_2SO_4	50%	+	+	+	+		+	+	+	+	+	+	+			
		60%	+	+	+	+			+	+	+	+	+	+	287.5	142	
		70%	+	+	+	+			+	+	+	+	o	—			
		80%	+	+	+	+			+	+	+	+	o	—			
		90%	+	+	+	o			+	+	o	—					
		93%	+	+	—	—											
		97%	+	+	—	—			+	+	o	—					
Sulfuric acid + chlorine water			+	+	+	+											
oleum		10% SO_3							+	o							
		30% SO_3							—								
		65% SO_3							—								
Sulfonitric acid	65% SO_4 / 20% NO_3 / 15% H_2O		+	+	+												
Thionyl chloride	$SOCl_2$									—							

Inorganic Media

Medium	Formula	Conc.	Solid SOLEF PVDF						SOLEF PVDF Used As Coating						B.P.		Remarks
			Temperature Of Medium - °F / °C														
			77 25	122 50	212 100	257 125	302 150	B.P.	77 25	122 50	167 75	212 100	257 125	B.P.	°F	°C	
Tin																	
(II) chloride	$SnCl_2$	50%	+	+	+	+			+	+	+						
(IV) chloride	$SnCl_4$	50%	+	+	+				+	+	+	+					
Water	H_2O		+	+	+	+	+	+	+	+	+	o	o	o			
Zinc																	
chloride	$ZnCl_2$	50%	+	+	+	+		+	+	+	+	+			231	110.5	
nitrate	$Zn(NO_3)_2 \cdot 6H_2O$	50%	+	+	+	+		+	+	+	+	+			242.5	117	
sulfate	$ZnSO_4 \cdot 7H_2O$	sat.	+	+	+	+		+	+	+	+				220	104.5	
Organic Media																	
Acetaldehyde		40%	+	+	+	o			+	o	—						
		100%	—														
trichloro -														—	208.4	98	
Acetic acid		100%	+	+	o	—			+	+	+	—			245.5	118.5	
		50%	+	+	o			o	+			-			215.5	102	
monochloro -		100%			—						o	—			372	189	
		75%							+								
		50%	+	—					+	—	—	—					
dichloro -		50%	+	+	o				+	+	—						
trichloro -		100%							+	+	o	—			388.5	198	
		50%	+	+					+	+	+	—					
hydroxy -		65%	+	+	+				+	+	+	+					
methylchlorophenoxy -			+	+	+												
-, anhydride			—						+								Becomes brown
-, chloride									—								
-, butyl ester			+	+	+				+	+	+	+					
-, cyclohexyl ester			+	+	+				+	+	+	—					
-, ethyl ester			+	+	+				+	+	+	+					
-, 2 ethoxyethyl ester								—	+	+	+	+			313.5	156	Destroyed
-, 1-pentyl ester			+	+	o	—			+	+	+	+					
-, nitrile			+						+								Swelling
Acetone see 2-propanone																	
Acetophenone			+	+	+				+*	+	+	+					
Acetonitrile see acetic acid, nitrile																	
Acrylic acid see propenoic acid																	
Acrylonitrile see propenoic acid nitrile																	
Allyl chloride see 3-chloropropene																	
Amine																	
diethyl -						—											
diethyl-2,2'-dihydroxy -					—	—											
dimethyl -			o						—								
triethyl -			+	—					+	—							Becomes brown
2,2',2''-tri(hydroxyethyl)			+			—			+	o							
Amyl alcohol see 1-pentanol																	
Aniline			+	+	—	—			+	+	+	—					Destroyed at 100°C
dimethyl -			+						+	+	+	—					
Benzaldehyde			+						+	+	+	+					
Benzene			+	+				+	+	+	+			+	176.2	80.1	
chloro -			+	+	o				+	+	+	+			269.6	132	
p-dibromo			+	+	+	o											
1,2-dichloro -									+	+	+	+	+				

Organic Media

Medium	Conc.	Solid SOLEF PVDF						SOLEF PVDF Used As Coating						B.P.		Remarks
		Temperature Of Medium - °F / °C														
		77 25	122 50	212 100	257 125	302 150	B.P.	77 25	122 50	167 75	212 100	257 125	B.P.	°F	°C	
Benzene (cont.)																
1,2,3 trihydroxy	50%	+	+													
nitro -		+	+	+				+	+	+	+					Becomes black
Benzenesulfonic acid									+	+	o	—				
2-chloro -	80%			+					+							
Benzoic acid	sat.	+	+	+												
2-hydroxy -	sat.	+	+	+			+	+						214	101	
3,4,5, trihydroxy	sat.	+							—							
-, chloride		+						—	—							
Benzyl alcohol see -hydroxytoluene																
Benzyl chloride see -chlorotoluene																
Butane 1,chloro		+	+				+									
Butanedioic acid																
2,3-dihydroxy	sat.	+	+	+			+							223	106	
	50%	+	+	o				+	+	+	+					
1-Butanol		+	+	o			o	+			—			243.5	117.5	
2-Butanol		+	+	+			+	+						211	99.5	
t-Butanol see 2-methyl-2-propanol																
Butanoic acid						o	o							325	163	
2-Butanone		+		—	—			+								
2-Butenol		+	o													
Cis-Butene dioic acid	50%	+	+	+	+											
i-Butylamine see 1-amino-2-methylpropane																
Cellosolve acetate see Acetic acid, 2-ethoxyethyl ester																
Chloroform see trichloromethane																
Citric acid	50%	+	+	+	+			+	+	+	+					
Cyclohexane		+	+				+	+	+					178	81	
Cyclohexanol		+		—				+			—			322	161.1	
Cyclohexanone		+	+					+	+		—			312.3	155.7	
Diisobutylene see 2,5-dimethyl-1,5-hexadiene																
Diacetone alcohol see 4-hydroxy-4-methyl-2-pentanone																
Diisobutylketone see 2,6-dimethy1-4-heptanone																
1,4-Dioxane		o	—	—			—	o	—	—	—		—	214	101	
Dodecanethiol		+	+	+				+	+	+	+					
Dodecanoic acid, chloride		+	+	+	+		o	+						293	145	Becomes black
Epichlorohydrin see 2-chloro-1,3-epoxypropane																

Organic Media

Medium	Conc.	Solid SOLEF PVDF 77/25	122/50	212/100	257/125	302/150	B.P.	SOLEF PVDF Used As Coating 77/25	122/50	167/75	212/100	257/125	B.P.	B.P. °F	B.P. °C	Remarks
Ethane																
1,2-diamine -		+	+	o			—				—			242	116.5	Becomes brown at 25°C
1,2-dibromo -		+	+	+	+		+							268	131	
1,2-dichloro -		+	+				+	+	+	+			+	183	84	
1,1,2-trifluoro-1,2,2-trichloro-		+					+	+					+	117.9	47.7	
1,2-Ethanedithiol		+	+	+	+	+		+								
Ethanethiol		+					+	+					+	98.5	37	
Ethanol		+	+				+	+	+	+			+	173	78.5	
2-amino -					—			+	—							
2-chloro -		+														
2-mercapto -											—					
Ethene																
tetrachloro -		+	+	o			o	+	+	+	o		o	250	121	Becomes black
trichloro -		+	+				+	+	+	+			+	188.5	87	Becomes black
Ether																
- diiso amyl								+	+	+	+	+				
- dibutyl,3,3'-dimethyl		+	+	+	+											
- dibutyl								+	+	+	+	+	+	287	142	
- diethyl		+					+	+					+	94	34.4	
- diisopropyl								+	+				+	156	69	
- diphenyl								+	+	+	+	+				
Ethylene: see ethene - chlorohydrin: see 2-chloroethanol - diamine: see 1,2-diamino-ethane - glycol: see 1,2-ethanediol																
Ethylmercaptan: see ethanethiol																
Formaldehyde	37%	+	+	+	+											
Formic acid	98%	+	+	+	+		+							213.3	100.7	
	80%	+	+	+	+			+	+	+	+					
	60%	+	+	+	+			+	+	+	o					
	50%	+	+	+	+											
-Chloro																
-, p-t-butyl cyclohexyl ester		+	+					o	—							
-, ethyl ester		+	+					o	—							
-, methyl ester		+	+					o	—							
Fumaric acid	sat.	+	+	o				+								
Furane		+					+	+					+	90	32	
tetrahydro -		+	+				+	+	+				+	149	65	Swelling
Furfural		+	o	—				+			—		323	161.7		
d-glucose		+	+	+	+			+	+	+	+	+				
Glutamic acid	sat.	+	+	+				+	+	+	+					
Glycerin: see Glycerol																
Glycerol		+	+	+	+			+								
Glycolic acid: see hydroxyacetic acid																
Heptane		+	+	+			+	+					+	209.1	98.4	
Heptanol																
2,6 dimethyl-4-heptanol		+	+	+			+									
Heptanone																
2,6 dimethyl-4-heptanone		+	+	o	o	o	o	+						334	168	
Hexadiene																
2,5 dimethyl-1,5-hexadiene		+	+	+	+		+	+						273	134	
Hexane		+	+				+	+	+				+	154.5	68	

Organic Media

Medium	Conc.	Solid SOLEF PVDF						SOLEF PVDF Used As Coating						B.P.		Remarks
		Temperature Of Medium - °F / °C														
		77 25	122 50	212 100	257 125	302 150	B.P.	77 25	122 50	167 75	212 100	257 125	B.P.	°F	°C	
Isophorone								+	+	+						
Isovalerone see 2,6-dimethyl-4-heptanone																
Lactic acid see 2-hydroxypropanoic acid																
Lauryl chloride see dodecanoic acid, chloride																
Laurylmercaptan see dodecanethiol																
Methane																
dichloro -		+						+	+	+				105	41	
nitro -		+	o					+						213.4	100.8	Swelling
tetrachloro -		+	+				o	+	+	+			+	170.1	76.7	
trichloro -		+	+					+	+				+	142.2	61.2	
triiodo - (50% solution in alcohol)		+	+				+							187	86	
Methanol		+	+	o	o		+	+						148.4	64.7	
Methyl methacrylate - see 2-methyl propenoic acid - methyl ester																
Methylene chloride see dichloromethane																
Methylethylketone see 2-butanone																
Methylisobutylketone see 4-methyl-2-pentanone																
Morpholine		+	+					—						262	128	Becomes yellow
Naphthalene						o						o				Softens
Nicotinic acid see 3-pyridine carboxylic acid																
9-Octadecenoic acid (cis)		+	+	+	+	o		+	+	+	+	o				
Oleic acid see 9-octadecenoic acid (cis)																
Oxalic acid	sat.	+	+													
	50%	+	+	+				+	+	+	+					
1-Pentanol		+	+	+	o		o	+						279.1	137.3	
2-Pentanol		+	+					+	+							
Pentanone																
4-methyl-2-pentanone		+						+								
4-hydroxy-4-methyl-2-pentanone		o														
Phenol	100%	+	+	+				+	+	+	+					
	5%	+	+	+	+											
2,4,6-trinitro -	50%	+	+	+	+	o										
	10%	+	+	+				+	+	+	—					
Phosphoric acid - tributyl ester		+														
Phthalic acid -, dimethyl ester		+	+	o				+			o					
Picric acid see 2,4,6-trinitrophenol																
Piperazine	60%	+	+	+	+									293	145	Becomes dark

Organic Media

Medium	Conc.	Solid SOLEF PVDF						SOLEF PVDF Used As Coating						B.P.		Remarks
		Temperature Of Medium - °F / °C														
		77 / 25	122 / 50	212 / 100	257 / 125	302 / 150	B.P.	77 / 25	122 / 50	167 / 75	212 / 100	257 / 125	B.P.	°F	°C	
Propane																
1-amino-2-methyl -		o						—								Becomes brown
2-amino-2-methyl -		+														
2-chloro-1,3-epoxy -		+						+								
1,2 dichloro -				o												
1,2,3,-trichloro -					o											
1,2-epoxy -		+					o	+						95	35	
1,2-Propanediol																
-carbonate								+	+	+						
Propanoic acid																
2-hydroxy -	50%	+														
	75%	+	+	+				+	+	+	+					
	100%							+	+	+	+	+				
Methylchlorophenoxy propanoic acid		+	+	+												
1-Propanol		+	+				o	+						208.8	97.1	
2-methyl-2-propanol		+	+				+	+						180	82.2	
Propanone	100%	+	+					+	+				+	133.2	56.2	Swelling
	50%	+						+								
Propane		+														
3-chloro -		+					+	+					+	113	45	
Propanoic acid		+						+								
-, nitrile		o						+						171.5	77.5	
-, ethyl ester		o												211.6	99.8	
-, methyl ester		o						+								
2-methyl propanoic acid																
- methyl ester								+								
Propylene see propene -carbonate : see 1,2-Propaned[illegible]arbonate -oxide: see 1,2-epoxypropane																
Pyridine		+	+	—				+	+		—			240	115.5	Becomes yellow
-3,carboxylic acid	sat.	+	+	+				–			–					
Pyrogallol see 1,2,3-trihydroxybenzene																
Salicylic acid see 2-hydroxybenzoic acid																
Stilbene	6%							+	+	+						
Tannic acid	sat.	+	+	+			+									
Tartaric acid see 2,3-dihydroxybutanedioic acid																
Toluene		+	+	+			+	+	+	+	+			231.1	110.6	
-chloro -						—		—	—	—	—					Dissolves
-hydroxy -					o	—		+	+	+	+					Dissolves
Triethanolamine see 2,2'2''-trihydroxytriethylamine																
Urea		+	+	o				+	+		o					
Xylene				—				+	+	+	—					

Miscellaneous Media

Medium	Conc.	Solid SOLEF PVDF 77/25	122/50	212/100	257/125	302/150	B.P.	SOLEF PVDF Used As Coating 77/25	122/50	167/75	212/100	257/125	B.P.	B.P. °F	B.P. °C	Remarks
		Temperature Of Medium - °F / °C														
Bourguignonne sauce		+	+	+	+			+								
Brandy		+	+	+	+		+									
Clove Oil		+														
Cooking fat		+	+	+	+			+								
Ketchup		+	+	+	+			+								
Lard		+	+	+	+			+								
Linseed oil		+	+	+	+			+								
Milk		+	+	+			+	+								
Mustard		+	+	+	+	+		+								
Tap water		+	+	+	+		+	+	+	+	o			212	100	
Tea		+	+	+			+	+						212	100	
Crude Oil		+	+	+	+			+	+	+	+o					
Diesel fuel		+	+				+	+	+	+			+	194	90	Becomes black
Flushing oil		+	+	+	+	+										Becomes brown
Light oil		+	+				+	+	+				+	158	70	Becomes black
Gasoline		+	+	+	+			+	+	+	+					Becomes black
Mineral oil		+	+	+	+			+	+	+	+					Becomes black
Shell Tellus 72 oil		+	+	+	+	+										Becomes brown
Shell Tellus 27 oil		+	+	+	+	+										Becomes brown
Shell Tellus 15 oil		+	+	+	+	+										Becomes brown
Shell Tellus 29 oil		+	+	+	+	+										Becomes brown
Shell Macoma 82 oil		+	+	+	+	+										
Shell Macoma 72 oil		+	+	+	+	+										
Shell Macoma 60 oil		+	+	+	+	+										
Shell Talpa 60 oil		+	+	+	+	+										Becomes brown
Shell Talpa 30 oil		+	+	+	+	+										Becomes brown
Shell 20/20 oil		+	+	+	+	+										
Shell Vitrea 30 oil		+	+	+	+	+										Becomes brown
Shell Vitrea 75 oil		+	+	+	+	+										Becomes brown
Shell Vitrea 41 oil		+	+	+	+	+										Becomes brown
Shell Voluta 270 oil		+	+	+	+	+										Becomes brown
Shell Voluta 45 oil		+	+	+	+	+										Becomes brown
Shell ATF Dexron oil		+	+	+	+	+										
UCB Spaino oil		+	+	+	+	+										Becomes brown
Caltex URSA 50 oil		+	+	+	+	+										Becomes brown
Danoel G oil		+	+	+	+	+										Becomes brown
Mobil compounds BB		+	+	+	+	+										Becomes brown
Mobil compounds light		+	+	+	+	+										Becomes brown
Yacco Y oil		+	+	+	+	+										Becomes brown
Aqua regia		o						—								
Bromine water		+	+	+							—					
Sea water		+	+	+			+	+	+	+	o		o	217	103	
H_2SO_4 : HNO_3 (1:1)		+	+					+								
Kerosene		+	+				+	+	+				+	158	70	
Naphtha		+	+					+								
Skydrol 500 B		+	+	+	+											
Xylol technical		+	+	+	o		o	+	+	+	—			284	140	

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National or local regulations on industrial safety and hygiene are applicable in all cases; in no case can we accept any responsibility for non-observance.

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APPENDIX F

PROPERTIES OF PLASTICS

Extracted from Perry's Chemical Engineer's Handbook, Sixth Edition, Don W. Green, Editor, (c) 1984 by McGraw-Hill, Inc., pp 23-48 to 23-57.

Table F-1. Chemical Resistance of Important Plastics

	Poly-propylene poly-ethylene	CAB*	ABS†	PVC‡	Saran§	Polyester glass¶	Epoxy glass	Phenolic asbestos	Fluoro-carbons	Chlorinated polyether (Penton)	Poly-carbonate
10% H_2SO_4	Excel.	Good	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
50% H_2SO_4	Excel.	Poor	Excel.	Excel.	Excel.	Good	Excel.	Excel.	Excel.	Excel.	Excel.
10% HCl	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
10% HNO_3	Excel.	Poor	Good	Excel.	Excel.	Good	Good	Fair	Excel.	Excel.	Excel.
10% Acetic	Excel.	Good	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
10% NaOH	Excel.	Fair	Excel.	Good	Fair	Fair	Excel.	Poor	Excel.	Excel.	Excel.
50% NaOH	Excel.	Poor	Excel.	Excel.	Fair	Poor	Good	Poor	Excel.	Excel.	Excel.
NH_4OH	Excel.	Poor	Excel.	Excel.	Poor	Fair	Excel.	Poor	Excel.	Excel.	Excel.
NaCl	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
$FeCl_3$	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
$CuSO_4$	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
NH_4NO_3	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Good	Excel.	Excel.	Excel.
Wet H_2S	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	
Wet Cl_2	Poor	Poor	Excel.	Good	Poor	Poor	Poor	Excel.	Excel.	Excel.	
Wet SO_2	Excel.	Poor	Excel.	Excel.	Good	Excel.	Excel.	Excel.	Excel.	Excel.	
Gasoline	Poor	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
Benzene	Poor	Poor	Poor	Poor	Fair	Good	Excel.	Excel.	Excel.	Fair	Fair
CCl_4	Poor	Poor	Poor	Fair	Fair	Excel.	Good	Excel.	Excel.	Fair	Poor
Acetone	Poor	Poor	Poor	Poor	Fair	Poor	Good	Poor	Excel.	Good	Good
Alcohol	Poor	Poor	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.

NOTE: Ratings are for long-term exposures at ambient temperatures [less than 38°C (100°F)].
*Cellulose acetate butyrate.
†Acrylonitrile butadiene styrene polymer.
‡Polyvinyl chloride, type I.
§Chemical resistance of Saran-lined pipe is superior to extruded Saran in some environments.
¶Refers to general-purpose polyesters. Special polyesters have superior resistance, particularly in alkalies.

Table F-2. Typical Property Ranges for Plastics

Thermosets[a]	Specific gravity	Tensile strength		Modulus of elasticity, tension		Impact strength, Izod[b]		Maximum use temperature (no load)		HDT at 254 lbf/in[c]		Chemical resistance[d]					
		kip	MPa	10^3kip/in^2	10^3MPa	ft·lb	J	°F	°C	°F	°C	Weather resistance	Weak acid	Strong acid	Weak alkali	Strong alkali	Solvents
Alkyds																	
Glass-filled	2.12–2.15	4–9.5	28–66	20–28	138–193	0.6–10	0.8–14	450	230	400–500	200–260	R	A	A	A	A	A
Mineral-filled	1.60–2.30	3–9	21–62	5–30	34–207	0.3–0.5	0.4–0.7	300–450	150–230	350–500	180–260	R	R	A	A	D	A
Asbestos-filled	1.65	4.5–7	31–48	.....	.....	0.4–0.5	0.6–0.7	450	230	315	160	R	R	S	R	S	R
Synthetic fiber-filled	1.24–2.10	4.5–7	31–48	20	138	0.5–4.5	0.7–6.1	300–430	150–220	245–430	120–220	R	R	S	R	S	A
Alkyl diglycol carbonate	1.30–1.40	5–6	34–41	3.0	21	0.2–0.4	0.3–0.5	212	100	140–190	60–90	R	R	A[e]	R	R-S	R
Diallyl phthalates																	
Glass-filled	1.61–1.78	6–11	41–76	14–22	97–152	0.4–15	0.5–20	300–400	150–200	330–540	165–280	R	R	S	R-S	S	R
Mineral-filled	1.65–1.68	5–9	34–62	12–22	83–152	0.3–0.5	0.4-1	300–400	150–200	320–540	160–280	R	R	S	R-S	S	R
Asbestos-filled	1.55–1.65	7–8	48–55	12–22	83–152	0.4–0.5	0.5–0.7	300–400	150–200	320–540	160–280	R	R	S	R-S	S	R
Epoxies (bis-A)																	
No filler	1.06–1.40	4–13	28–90	2.15–5.2	15–36	0.2–1.0	0.3–1.4	250–500	120–260	115–500	45–260	R	R	A	R	S	R-S
Graphite-fiber reinforced	1.37–1.38	185–200	1280–1380	118–120	814–827	.....	.....	.....	.....	.....	.....	S	R	R	R	R	R-S
Mineral-filled	1.6 –2.0	5–15	34–103	.....	.....	0.3–0.4	0.4–0.5	300–500	150–260	250–500	120–260	S	R	R	R	R	R-S
Glass-filled	1.7 –2.0	10–30	69–207	30	207	10–30	14–41	300–500	150–260	250–500	120–260	S	R	R-S	R	R	R-S
Epoxies (novolac): no filler	1.12–1.24	5–11	34–76	2.15–5.2	15–36	0.3–0.7	0.4–0.9	400–500	200–260	450–500	230–260	R	R	R	R	R	R
Epoxies (cycloaliphatic): no filler	1.12–1.18	10–17.5	69–121	5–7	34–48	.....	.....	480–550	250–290	500–550	260–290	R	R	R-A	R	R-A	R
Melamines																	
Cellulose-filled	1.45–1.52	5–9	34–62	11	76	0.2–0.4	0.3–0.5	250	120	270	130	S	R-S	D	R	D	R
Flock-filled	1.50–1.55	7–9	48–62	.....	.....	0.4–0.5	0.5–0.7	250	120	270	130	S	R-S	D	R	D	R-S
Asbestos-filled	1.70–2.0	5–7	34–48	20	138	0.3–0.4	0.4–0.5	250–400	120–200	265	130	S	R-S	D	S	S	R
Fabric-filled	1.5	8–11	55–76	14–16	97–110	0.6–1.0	0.8–1.4	250	120	310	150	S	R	D	R	A	R-S
Glass-filled	1.8 –2.0	5–10	34–69	24	165	0.6–18	0.8–24	300–400	150–200	400	200	S	R	D	R	R-S	R
Phenolics																	
Wood-flour-filled	1.34–1.45	5–9	34–62	8–17	55–117	0.2–0.6	0.3–0.8	300–350	150–180	300–370	150–190	S	R-S	S-D	S-D	A	R-S
Asbestos-filled	1.45–2.00	4.5–7.5	31–52	10–30	69–207	0.2–0.4	0.3–0.5	350–500	180–260	300–500	150–260	S	R-S	S-D	S-D	A	R-S
Mica-filled	1.65–1.92	5.5–7	38–48	25–50	172–345	0.3–0.4	0.4–0.5	250–300	120–150	300–350	150–180	S	R-S	S-D	S-D	A	R-S
Glass-filled	1.69–1.95	5–18	34–124	19–33	131–228	0.3–18	0.4–24	350–550	180–290	300–600	150–320	S	R-S	S-D	S-D	A	R-S
Fabric-filled	1.36–1.43	3–9	21–62	9–14	62–97	0.8–8	1.1–11	220–250	100–120	250–330	120–170	S	R-S	S-D	S-D	A	R-S
Polybutadienes																	
Very high vinyl (no filler)	1.00	8	55	2	14	1.1	1.5	500	260	.....	.....	S	R	R	R	R	R
Polyesters																	
Glass-filled BMC	1.7 –2.3	4–10	28–69	16–25	110–172	1.5–16	2.0–22	300–350	150–180	400–450	200–230	R-E	R-A	S-A	S-A	S-D	A-D
Glass-filled SMC	1.7 –2.1	8–20	55–138	16–25	110–172	8–22	11–30	300–350	150–180	400–450	200–230	R-E	R-A	S-A	S-A	S-D	A-D
Glass-cloth reinforced	1.3 –2.1	25–50	172–345	19–45	131–310	5–30	7–41	300–350	150–180	400–450	200–230	R-E	R-A	S-A	S-A	S-D	A-D
Silicones																	
Glass-filled	1.7 –2.0	4–6.5	28–45	10–15	69–103	3–15	4–20	600	320	600	320	R-S	R-S	R-S	S	S-A	R-A
Mineral-filled	1.8 –2.8	4–6	28–41	13–18	90–124	0.3–0.4	0.4–0.5	600	320	600	320	R-S	R-S	R-S	S	S-A	R-A
Ureas																	
Cellulose-filled	1.47–1.52	5.5–13	38–90	10–15	69–103	0.2–0.4	0.3–0.5	170	80	260–290	130–140	S	R-S	A-D	S-A	D	R-S
Urethanes																	
No filler	1.1 –1.5	0.2–10	1–69	1 –10	7–69	5–NB	7	129–250	90–120	.....	.....	R-S	S	A	S	S-A	R-S

Table F-2. Typical Property Ranges for Plastics (Continued)

Thermoplastics	Specific gravity	Tensile strength		Modulus of elasticity tension		Impact strength, Izod[b]		Maximum-use temperature (no load)		HDT at 66 lbf/in²		HDT at 264 lbf/in²		Chemical resistance[d]					
		kip/in²	MPa	10³kip/in²	10³MPa	ft·lb	J	°F	°C	°F	°C	°F	°C	Weather resistance	Weak acid	Strong acid	Weak alkali	Strong alkali	Solvents
ABS																			
GP	1.05–1.07	5.9	41	3.1	21	6	8	160–200	70–90	210–225	100–110	190–206	90–95	R-E	R	A[e]	R	R	A[f]/R
High-impact	1.01–1.06	4.8	33	2.4	17	7.5	10	140–210	60–100	210–225	100–110	188–211	85–100	R-E	R	A[f]	R	R	A[f]/R
Heat-resistant	1.06–1.08	7.4	51	3.9	27	2.2	3.0	190–230	90–110	225–252	110–120	226–240	110–115	R-E	R	A[f]	R	R	A[f]/R
Trans.	1.07	5.6	39	2.9	20	5.3	7.1	130	55	180	80	165	75	R-E	R	A[f]	R	R	A[f]/R
	1.20	6.0	41	3.2	22	2.5	3.4	130–180	55–80	210–220	100–105	195	90	R-E	R	A[e]	R	R	A[f]/R
Acetals																			
Homopolymers	1.42	10	69	5.2	36	1.4	1.9	195	90	338	170	255	125	R	R	A	R	A-D	R
Copolymers	1.41	8.8	61	4.1	28	1.2–1.6	1.6–2.2	212	100	316	160	230	110	R	R	A	R	R	R
Acrylics																			
GP	1.11–1.19	5.6–11.0	39–76	2.25 4.65	16–32	0.3–2.3	0.4–3.1	130–230	55–110	175–225	80–110	165–210	75–100	R	R	A[e]	R	A	A[f]/R
High-impact	1.12–1.16	5.8–8.0	40–55	2.3–3.3	16–23	0.8–2.3	1.1–3.1	140–195	60–90	180–205	80–95	165–190	75–90	R	R	A[e]	R	R	A[f]/R
	1.21–1.28	8.0–12.5	55–86	3.5–4.8	24–33	0.3–0.4	0.4–0.5	125–200	50–90	170–200	75–95	155–205	70–95	R	R	A[e]	R	A	A[f]/R
Cast	1.18–1.28	9.0–12.5	62–86	3.7–5.0	26–34	0.4–1.5	0.5–2.0	140–200	60–90	165–235	75–115	160–215	70–100	R	R	A[e]	R	A	A[f]/R
Multipolymer	1.09–1.14	6–8	41–55	3.1–4.3	21–30	1–3	1–4	165–175	75–80	....	....	185–195	85–90	E	R	A[e]	H	S	A[f]
Cellulosics																			
Acetate	1.23–1.34	3.0–8.0	21–55	1.05–2.55	7–18	1.1–6.8	1.5–9	140–220	60–105	120–209	50–100	111–195	45–90	S	S	D	S	D	D-S
Butyrate	1.15–1.22	3.0–6.9	21–48	0.7–1.8	5–12	3.0–10.0	4–14	140–220	60–105	130–227	55–110	113–202	45–95	S	S	D	S	D	D-S
E cellulose	1.10–1.17	3–8	21–55	0.5–3.5	3–24	1.7–7.0	2.3–9.5	115–185	45–85	....	....	115–190	45–90	S	S	D	R	S	D
Nitrate	1.35–1.40	7–8	48–55	1.9–2.2	13–15	5–7	7–9	140	60	....	....	140–160	60–70	E	S	D	S	D	D
Propionate	1.19–1.22	4.0–6.5	28–45	1.1–1.8	8–12	1.7–9.4	2.3–13	155–220	70–105	147–250	65–120	111–228	45–110	S	S	D	S	D	D-S
Chloro polyether	1.4	5.4	37	1.5	10	0.4	0.5	290	140	285	140	....	....	R-S	R	A[e]	R	R	R
Ethylene copolymers																			
EEA	0.93	2.0	14	0.05	0.3	NB	....	190	90	....	....	....	....	S	R	A[e]	R	R	A-D
EVA	0.94	3.6	25	0.02–0.12	0.14–0.8	NB	....	....	....	140–147	60–65	93	35	S	R	A	R	R	A-D
Fluoropolymers																			
FEP	2.14–2.17	2.5–3.9	17–27	0.5–0.7	3–5	NB	....	400	208	158	70	....	....	R	R	R	R	R	R
PTFE	2.1–2.3	1.4	7–28	0.38–0.65	2.6–4.5	2.5–4.0	3.4–5.4	550	290	250	120	....	....	R	R	R	R	R	R
CTFE	2.10–2.15	4.6–5.7	32–39	1.8–2.0	12–14	3.5–3.6	4.7–4.9	350–390	180–200	258	125	....	....	R	R	R	R	R	S[g]
PVF_2	1.77	7.2	50	1.7	12	3.8	5.2	300	150	300	150	195	90	S	R	A[h]	R	R	R
ETFE and ECTFE	1.68–1.70	6.5–7.0	45–48	2–2.5	14–17	NB	....	300	150	220	105	160	70	R	R	R	R	R	
Methylpentene	0.83	3.3–3.6	23–25	1.3–1.9	10–13	0.95–3.8	1.3–5.2	275	135	....	....	....	....	E	R	A[h]	R	R	A
Nylons																			
6/6	1.13–1.15	9–12	62–83	3.85	27	2.0	27	180–300	80–150	360–470	180–240	150–220	165–105	R	R	A	R	R	R-D[i]
6	1.14	12.5	86	....	....	1.2	1.6	180–250	80–170	300–365	150–185	140–155	60–70	R	R	A	R	R	R-A[i]
6/10	1.07	7.1	49	2.8	19	1.6	2.2	180	80	300	150	....	....	R	R	A	R	R	R-A[i]
8	1.09	3.9	27			>16	>22							R	R	A	R	R	R-A[i]
12	1.01	6.5–8.5	45–59	1.7–2.1	12–14	1.2–4.2	1.6–5.7	175–260	80–125	....	....	120–130	50–55	R	R	A	R	R	R-A[i]

Table F-2. Typical Property Ranges for Plastics (Continued)

Thermoplastics	Specific gravity	Tensile strength kip/in²	Tensile strength MPa	Modulus of elasticity tension 10⁵kip/in²	Modulus of elasticity tension 10²MPa	Impact strength, Izod[b] ft·lb	Impact strength, Izod[b] J	Maximum-use temperature (no load) °F	Maximum-use temperature (no load) °C	HDT at 66 lbf/in² °F	HDT at 66 lbf/in² °C	HDT at 264 lbf/in² °F	HDT at 264 lbf/in² °C	Chemical resistance[d] Weather resistance	Weak acid	Strong acid	Weak alkali	Strong alkali	Solvents
Copolymers	1.08–1.14	7.5–11.0	52–76	....	....	1.5–19	2–26	180–250	80–120	....	....	130–350	55–180	R	R	A	R	R	R-A[f]
Polyesters																			
PET	1.37	10.4	72	....	....	0.8	1.1	175	80	240	115	185	85	R	R	A[e]	R	A	R-A[f]
PBT	1.31	8.0–8.2	55–57	3.6	25	1.2–1.3	1.6–1.8	280	140	310	155	130	55	R	R	R	R	A	R
PTMT	1.31	8.2	57	....	....	1.0	1.4	270	130	302	150	122	50	R	R	R	R	A	R
Copolymers	1.2	7.3	50	....	....	1.0	1.4					154	70						
Polyaryl ether	1.14	7.5	52	3.2	22	10	14	250	120	320	100	300	150	E	R	R	R	R	A
Polyaryl sulfone	1.36	13	90	3.7	26	2	2.7	500	260	....	....	525	275	Darkens	R	R	R	R	R
Polybutylene	0.910	3.8	26	0.26	1.8	NB		225	105	215	100	130	55	E	R	A[e]	R	R	
Polycarbonate	1.2	9	62	3.45	24	12–16	16–22	250	120	270–290	130–145	265–285	130–140	R	R	A[e]	A	A	A
PC-ABS	1.14	8.2	57	3.7	26	10	14	220	105	235	115	220	105	R-E	R	A[e]	R	S	A
Polyethylenes																			
LD	0.91–0.93	0.9–2.5	6–17	0.20–0.27	1.4–1.9	NB	...	180–212	80–100	100–120	40–50	90–105	30–40	E	R	A[e]	R	R	R
HD	0.95–0.96	2.9–5.4	20–37	....	....	0.4–14	0.5–19	175–250	80–120	140–190	60–90	110–130	45–55	E	R	R-A[e]	R	R	R
HMW	0.945	2.5	17	1	7	NB	....	....	....	155–180	70–80	105–180	40–80	E	R	A[e]	R	R	R
Ionomer	0.94–0.95	3.4–4.5	23–31	0.3–0.7	2–5	6-NB	8	160–180	70–80	110	45	100–120	40–50	E	A	A[e]	R	R	R
Phenylene oxide-based materials	1.06–1.10	7.8–9.6	54–66	3.5–3.8	24–26	5.0	68	175–220	80–105	230–280	110–140	212–265	100–130	R	R	R	R	R	R-A
Polyphenylene sulfide	1.34	10	69	4.8	33	0.3	0.4	500	260	....	....	278	135	R	R	A[e]	R	R	R
Polyimide	1.43	5–7.5	34–52	5.4	37	5–7	7–9	500	260	....	....	680	360		R	R	A	A	R
Polypropylenes																			
GP	0.90–0.91	4.8–5.5	33–38	1.6–2.2	11–15	0.4–2.2	0.5–3.0	225–300	105–150	200–230	95–110	125–140	50–60	E	R	A[e]	R	R	R
High-impact	0.90–0.91	3–5	21–34	1.3	9	1.5–12	2–16	200–250	95–120	160–200	70–95	120–135	50–60	E	R	A[e]	R	R	A
Propylene copolymer	0.91	4	28	1.0–1.7	7–12	1.1	1.5	190–240	90–115	185–230	85–110	115–140	45–60	E	R	A[e]	R	R	R
Polystyrenes																			
GP	1.04–1.07	6.0–7.3	41–50	4.5	31	0.3	0.4	150–170	65–80	....	....	180–220	80–105	S	R	A[e]	R	R	D
High-impact	1.04–1.07	2.8–4.6	20–32	2.9 4.0	20–28	0.7–1.0	0.9–1.4	140–175	60–80	....	....	175–210	80–100	S	R	A[e]	R	R	D
Polysulfone	1.24	10.2	70	3.6	25	1.2	1.6	300	150	360	180	345	175	S	R	R	R	R	R-A
Polyurethanes	1.11–1.25	4.5–8.4	31–58	0.1–3.5	0.7–24	NB	....	190	90	....	....	....	....	R-S	S-D	S-D	S-D	S-D	R
Vinyl, rigid	1.3–1.5	5–8	34–55	3–5	21–34	0.5–20	0.7–27	150–175	65–80	135–180	60–80	130–175	55–80	R	R	R-S	R	R	R-A
Vinyl, flexible	1.2–1.7	1–4	7–28	....	....	0.5–20	0.7–27	140–175	60–80	....	....	....	....	S	R	R-S	R	R	R-A
Rigid CPVC	1.49–1.58	7.5–9.0	52–62	3.6–4.7	25–32	1.0–5.6	1.4–7.6	230	110	215–245	100–120	200–235	95–115	R	R	R	R	R	R
PVC-acrylic	1.30–1.35	5.5–6.5	38–45	2.75–3.35	19–23	15	20	....	....	180	80	170	80	R	R	S	R	R	A
PVC-ABS	1.10–1.21	2.6–6.0	18–41	0.8–3.4	6–23	10–15	14–20	....	....	....	....	....	....	S	R	R-S	R	R	R-D
SAN	1.08	10–12	69–83	5.0–5.6	34–39	0.4–0.5	0.5–0.7	140–200	60–95	....	....	190–220	90–105	S-E	R	A	R	R	A

SOURCE: *Plastics Engineering Handbook*, 4th ed., Van Nostrand Reinhold, New York, 1976. Courtesy of National Association of Corrosion Engineers. To convert megapascals to pounds-force per square inch, multiply by 145.04.

[a] All values at room temperature unless otherwise listed.
[b] Notched samples.
[c] Heat-deflection temperature.
[d] Ac = acid, and Al = alkali; R = resistant; A = attached; S = slight effects; E = embrittles; D = decomposes.
[e] By oxidizing acids.
[f] By ketones, esters, and chlorinated and aromatic hydrocarbons.
[g] Halogenated solvents cause swelling.
[h] By fuming sulfuric.
[i] Dissolved by phenols and formic acid.

APPENDIX G

Extract from <u>Marine Corrosion: Causes and Prevention</u>
(c) J. Wiley and Sons, New York, 1975, pp. 302-305.

Table G. Properties of Coatings for Atmospheric Service

	Physical properties	Water resistance	Acid resistance	Alkali resistance	Solvent resistance	Temperature resistance	Weathering	Recoating
Alkyd								
Short-oil alkyd	Hard	Fair	Fair	Poor	Fair	Good	Fair	Easy
Long-oil alkyd	Flexible	Fair	Poor	Poor	Poor	Good	Good	Easy
Silicone alkyd	Tough	Good	Fair	Poor	Fair	Best of group	Very good	Fair
Vinyl alkyd	Tough	Good	Best of group	Poor	Fair	Fair	Very good	Difficult
Vinyl								
Polyvinyl chloride acetate copolymers	Tough	Very good	Excellent	Excellent	(Aliphatic hydrocarbon, good; aromatic hydrocarbon, poor)	Fair, 150°F	Very good	Easy
Vinyl acrylic copolymers	Tough	Good	Very good	Very good	(Aliphatic, good; aromatic, poor)	Fair, 150°F	Excellent	Easy
Chlorinated rubber								
Resin-modified	Hard	Very good	Very good	Very good	(Aliphatic, good, aromatic, poor)	Fair	Good	Easy
Alkyd modified	Tough	Good	Fair	Fair	(Aliphatic, good, aromatic, poor)	Fair	Very good	Easy
Water base								
Polyvinyl acetate	Scrub-resistant	Poor	Poor	Poor	Poor	Fair	Very good	Easy
Acrylic polymers	Scrub-resistant	Poor	Po...	Poor	Poor	Fair	Excellent	Easy
Epoxy	Tough	Good	Good	Good	Good	Good	Fair	Difficult
Epoxy								
Epoxyamine	Hard	Good	Good	Good	Very good	Very good	Fair; chalks	Difficult
Epoxy polyamide	Tough	Very good	Fair	Excellent	Fair	Good	Good; chalks	Difficult
Epoxy coal tar	Hard	Excellent	Good	Good	Poor	Good	Poor	Difficult
Epoxyester	Flexible	Good	Fair	Poor	Fair	Good	Good; chalks	Reasonable
Polyurethane								
Air-drying polyurethane varnish	Very tough	Fair	Fair	Fair	Fair	Good	Yellowing	Requires care
Two-package-reactive polyurethane	Tough, hard	Good	Fair	Fair	Good	Good	Some yellowing and chalking	Difficult
Moisture-reactive polyurethane	Very tough, abrasion-resistant	Fair	Fair	Fair	Good	Good	Fades in light; yellows in shade	Difficult
Nonyellowing polyurethane	Fairly hard to rubbery	Good	Fair	Fair	Good	Good	Very good	Difficult
Inorganic zinc								
Water base (sodium or potassium silicate)	Tough, abrasion-resistant, excellent chemical bond	Good	Poor	Poor	Excellent	Excellent	Excellent; unaffected by weather	Easy
Organic base (ethyl silicate)	Tough, hard; excellent bond	Good	Poor	Poor	Good	Excellent	Excellent	Easy

SOURCE: F. L. LaQue, *Marine Corrosion: Causes and Prevention*, Wiley, New York, 1975, pp. 302–305. Courtesy of National Association of Corrosion Engineers.

APPENDIX H

Approximate Container Costs for Selected Container Materials

Approximate Unit Container Costs
(representative order of 100,000 units)

COMPANY	DS2 CONTAINER SIZE 1-1/3 QUART 1.26 LITER	3.7 GALLON 14 LITER	5 GALLON 18.9 LITER
		STAINLESS STEEL	
Mutual Stamping Co. (closed head, "Visegrip" seal) (203) 877-3933	not available	$38.00 (3-gallon) Cylindrical Only	$41.00
Packaging Specialties (216) 271-7988	not available	not available	$45.00
James T. Waring & Sons (24 guage, 304 Stainless) (301) 322-5400	not available	$35.00 (Cylindrical)	$40.00
		LINED-STEEL DRUMS	
Van Leer Containers (epoxy, phenolic, or epoxy-phenolic liner) (800) 323-3151	not available	$4.35 (cylindrical only)	$4.50
Packaging Specialties (216) 271-7988	not available	not available	$16.75
		POLYMERS	
Air Products (AIROPAK) (fluorinated polyethylene) Discounts negotiable (800) 247-6725	$0.339 (1 quart) $0.458 (2 quart)	not available	$2.75 (2x 2-1/2 gallon)
Melmat, Inc. (Rotationally molded cross-linked polyethylene & polyurethane, 0.160" thick) (213) 325-1625	not available	$28.40 (5000 units/yr/head) ($2000 /head)	$26.30 (5000 units/yr/head) ($1200 /head)
Sunoco Plasticdrum (polyethylene) Discounts negotiable (815) 838-7210	not available	not available	$11.50 (14 gallon)